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DEPOSITS OF RADIOACTIVE CERITE NEAR JAMESTOWN, COLORADO*

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ABSTRACT

Cerite, a rare silicate of the cerium metals, occurs in small deposits in the pre-Cambrian rocks of the Front Range near Jamestown, Colorado. They are near the north border of a stock of Silver Plume granite, to which they are genetically related. Numerous lenticular schist masses in the granite suggest proximity to the roof.

The cerite rock containing about 75 per cent of cerite occurs as irregular lenses, one-fourth of an inch to 15 inches wide, in narrow aplite-pegmatite zones along the borders of small schist areas. Narrow veinlets of black allanite border the cerite rock and minute grains of uraninite (pitchblende) and pyrite are locally present.

Microscopic examination of the cerite rock shows it to be finely intergrown with

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varying amounts of allanite, brown epidote, törnebohmite, fluorite, bastnäsite, monazite, uraninite, and quartz. An analysis of the purer cerite rock showed 56 per cent of rare-earth oxides. A gray variety consisting chiefly of cerite, fluorite, and a brown epidote was found to show mild radioactivity on a photographic plate. An analysis of this material showed 0.513 per cent U_3O_8, 0.28 per cent ThO_2, 0.07 per cent PbO, and gave an age determination of 940,000,000 years.

INTRODUCTION

Cerite, a silicate of the cerium metals, is a rare mineral. Only four occurrences have been recorded, two in Sweden, and one each in Russia and in Canada. The deposits near Jamestown, Colorado, are thus the fifth known occurrence and the first in the United States. The mineral is commonly massive and finely granular, highly modified crystals of short prismatic habit being known only from Sweden. The color varies from gray to clove-brown or cherry-red, and the luster is dull adamantine. The hardness is about 5.5 and the specific gravity of the mineral is high, being nearly 5 (4.86, 4.91).

Several deposits of this little known mineral were discovered a few years ago by Charles Mohr, an old prospector, of Jamestown, Colorado, in the pre-Cambrian complex of the Front Range, 2 miles northeast of Jamestown, and 33 miles northwest of Denver (Fig. 1). The massive

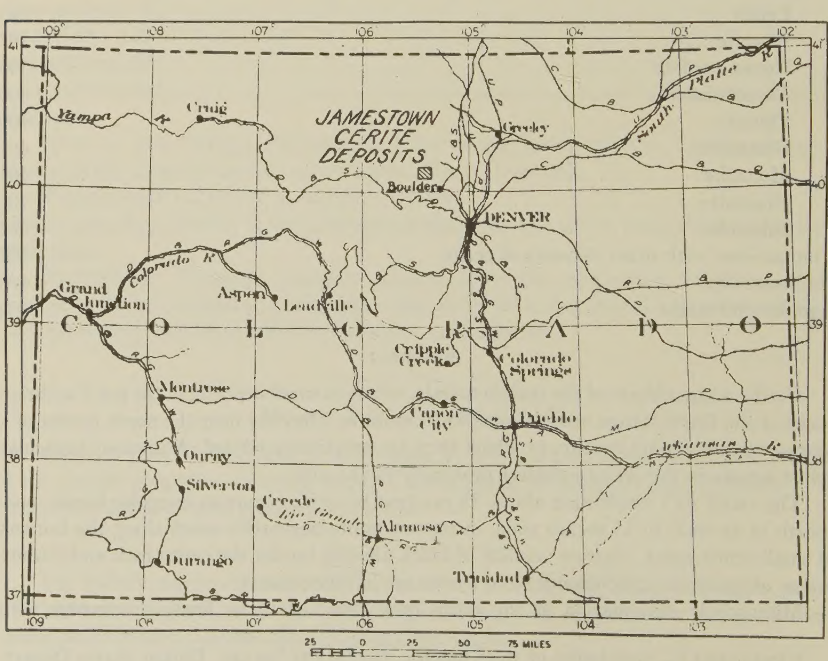

FIG. 1. Index map of Colorado showing the location of the Jamestown cerite deposits.

nondescript character of the material and its drab gray color give no indication of its unusual chemical composition, but its high specific gravity (4.65) would at once attract attention.

Several other rare-earth minerals are associated with the cerite, and the presence of radioactive materials makes possible a geologic age determination bearing a significant relationship to the widespread Silver Plume granite.

A comparison of the genetic and paragenetic relations of these deposits in Colorado to the other occurrences of cerite in the world are given in a later section of this paper.

The writers wish to acknowledge deep indebtedness to J. G. Fairchild and Charles Milton, of the U. S. Geological Survey Chemical Laboratory, for chemical analyses of some of the rare-earth minerals; to K. E. Lohman, of the U. S. Geological Survey, for making the photomicrographs; and to W. T. Schaller especially for many helpful suggestions during the preparation of this paper and for his analytical interpretation of the chemical data.

Geologic Occurrence

The pre-Cambrian rocks of the region consist of biotite schist and hornblende gneiss, which have been intruded by the Boulder Creek and Silver Plume granites and their associated pegmatites. These older rocks have been intruded by stocks and dikes of early Eocene (?) granodiorite and quartz monzonite. The chief rock in the vicinity of the cerite deposits is Silver Plume granite, the latest of the pre-Cambrian intrusives, which forms a large, irregular stock-like mass about 3 miles in diameter (Fig. 2). This mass is bordered on the north and southeast by schist and on the west by intrusive rocks of probable early Eocene age. Lenses and stringers of schist from 30 feet to half a mile long are scattered through the central part of the granite mass. In these inclusions, and in the bordering schist, the schistosity trends northeastward and dips steeply to the southeast. Dikes and lenses of pegmatite occur in the granite near the schist inclusions and in the bordering schist.

The cerite deposits appear to be near the central part of a granite stock, but detailed study of flow lines[1] in the granite (Fig. 2) seems to indicate that this granite body is composite, consisting of two separate stocks, and that the cerite deposits are actually near the border of a stock. The northern stock has a narrow rectangular outline, and is almost entirely free from schist inclusions. Its feeding channel was apparently

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[1] Balk, Robert, Structural behavior of igneous rocks: *Geol. Soc. Am., Memoir* **5**, 7–25 (July 1937).

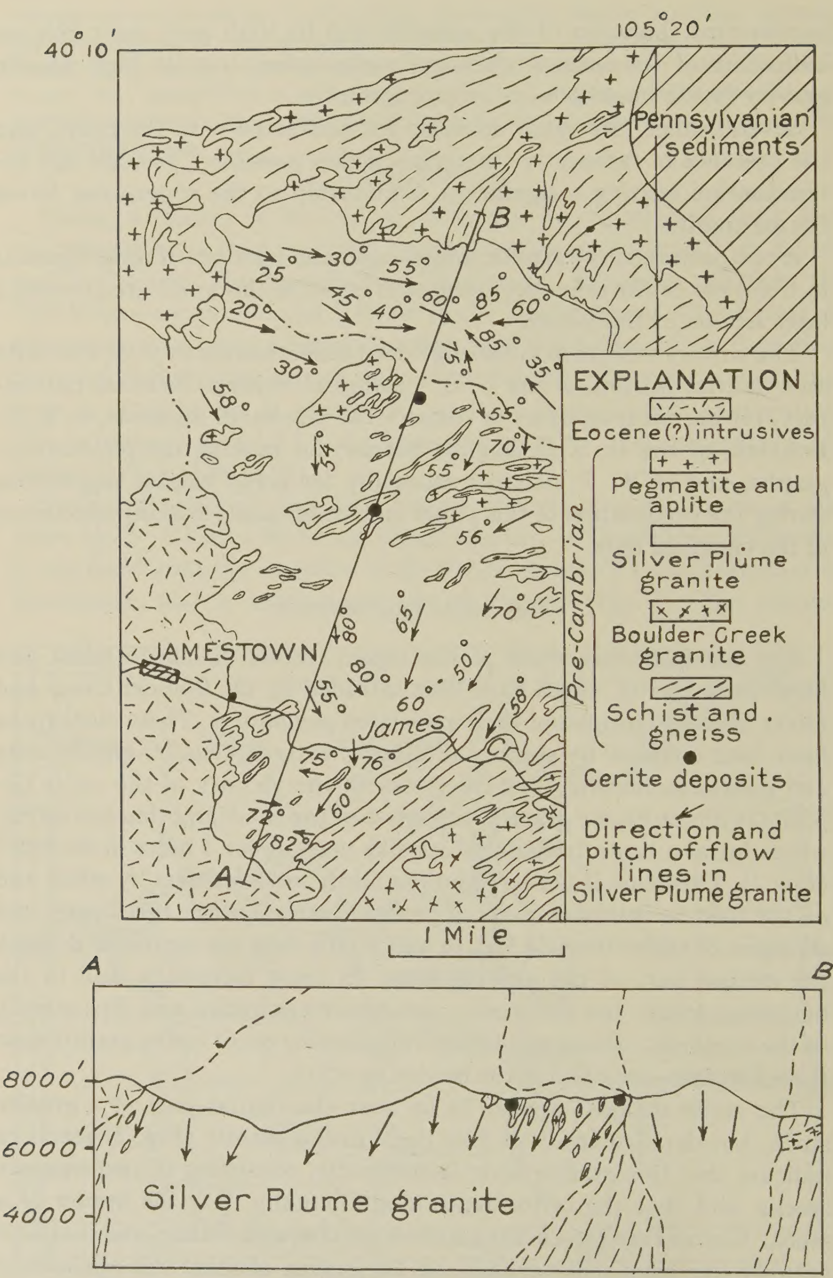


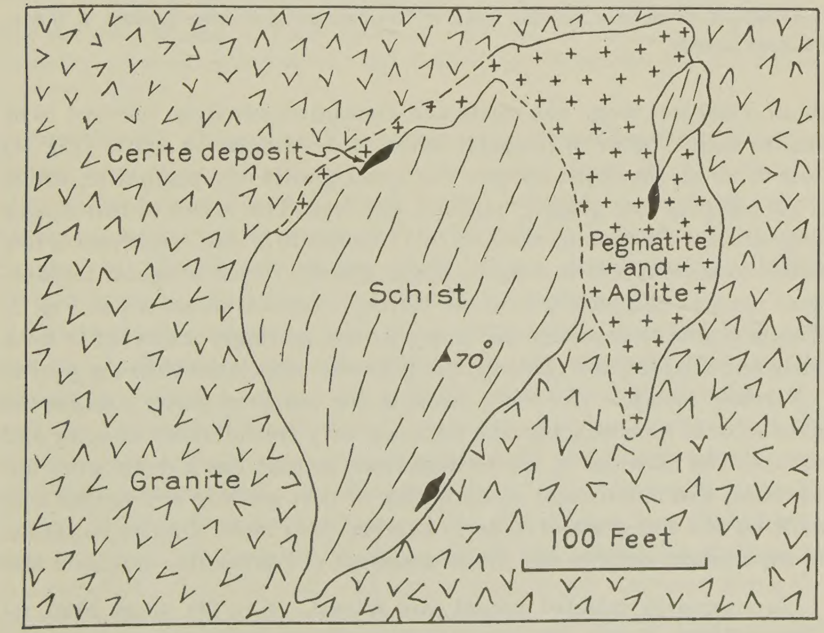
FIG. 2. Geologic plan and cross section of a part of the Jamestown district, showing the geologic setting of the cerite deposits.

beneath its center. The southern stock is roughly triangular in outline and contains abundant schist inclusions in its northern part. The magma appears to have come up from beneath the southern corner of the triangle and to have fanned out northward. If this interpretation is correct, the cerite deposits are near the north border of the southern stock, on the side away from the source of intrusion. The abundance of schist inclusions in the northern part of this stock, and their relative scarcity elsewhere, suggests that the present surface is closer to the roof in this locality than elsewhere. The supposed shape of the roof is shown in the cross section of Fig. 2.

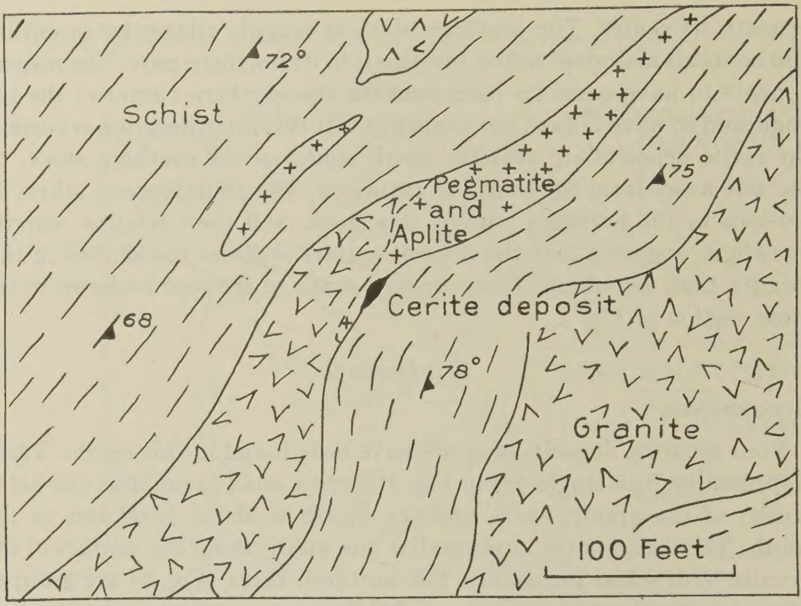
MINERALOGY

OCCURRENCE

Four separate deposits of cerite have been found in this region. Three (represented by a single dot in Fig. 2) form a small group near the north border of the granite stock and the fourth is about 3,600 feet to the south. The deposits are in pegmatite and aplite along the contact of the granite with schist inclusions. The northern three (Fig. 3) are grouped around a small schist lens about 300 feet long, and the southern one borders a long narrow tongue of granite which cuts a large schist mass



A



B

FIG. 3. Detailed geologic maps of the cerite localities showing the relation of the cerite deposits to the pre-Cambrian rocks. *A*. Northern group of cerite deposits. *B*. Southern cerite deposit.

about 3,000 feet long. The cerite and associated minerals, referred to as "cerite rock," occur in irregular lenses and stringers in aplite (Fig. 4) close to, or at, the schist border. The aplite grades into pegmatite, which in turn grades into granite within a few feet. The lenses of cerite rock range from a fraction of an inch to 15 inches in width, and from a few inches to several feet in length. Black allanite forms irregular replacement borders and locally cuts the cerite in veinlets as shown in Fig. 5. Minute grains of uraninite and of pyrite are sparingly scattered in both cerite and allanite, and chalcopyrite is locally associated with the pyrite.

Northern Group.—The cerite rocks in the northern group contain the same suite of minerals, but the minerals vary considerably in color and texture. The material in the northeastern deposit has a dense gray appearance, and microscopic examination of thin sections shows that it is made up of a fine-grained mosaic of cerite, deep violet fluorite,[2] allanite, brown epidote, quartz, and minor amounts of bastnäsite, uraninite and

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[2] In a previously published abstract (*Am. Mineral.*, **21**, p. 199, March 1936), the writers identified the deep violet mineral as yttrocerite, but further work has shown it to be fluorite.

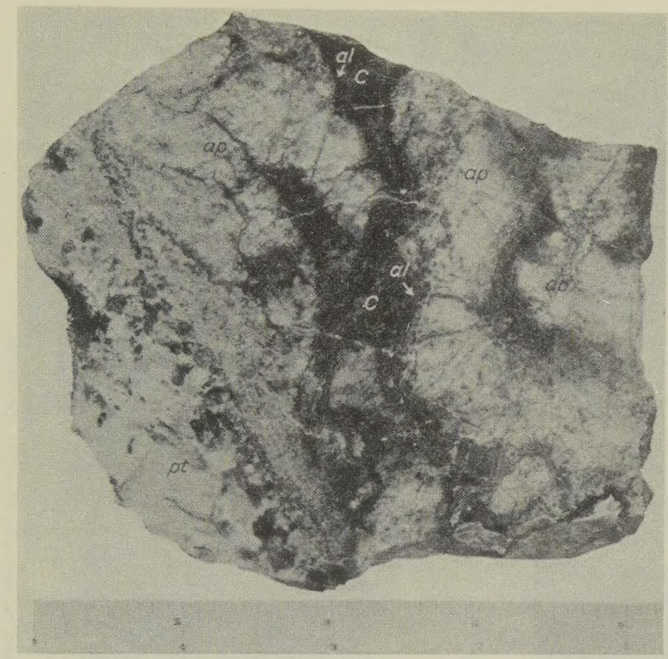

FIG. 4. (Scale in inches) Photograph of cerite specimen from northwestern deposit of northern group showing irregular veinlets of cerite rock (c) cutting aplite (ap) which grades into pegmatite (pt). A narrow band of allanite (al) borders the cerite, but is inconspicuous in places.

pyrite (Fig. 6). The grains are sub-angular to rounded and the grain size ranges from .01 to .11 millimeters, but averages about .03. The distribution of the minerals in this mosaic is very irregular. Cerite everywhere makes up more than 50 per cent of the material, but the fluorite content ranges from 10 to 25 per cent from place to place, the brown epidote from 10 to 20 per cent, and the quartz from 1 to 5 per cent.

Bands of black allanite border the cerite rock and are commonly one-half to 2 millimeters wide. The allanite has also replaced aplite on the other side of the black band, for euhedral crystals project into the aplite and are scattered through it for a distance of several inches from the allanite band. Quartz and orthoclase seem to have been equally susceptible to replacement. The allanite close to the cerite border is usually brown, whereas that farther away shows the green colors. This brown zone is absent, however, on the aplite side of the allanite band. Small to minute grains of pyrite and uraninite are sparingly scattered along the contact between cerite and allanite, and a few grains are found within the cerite.

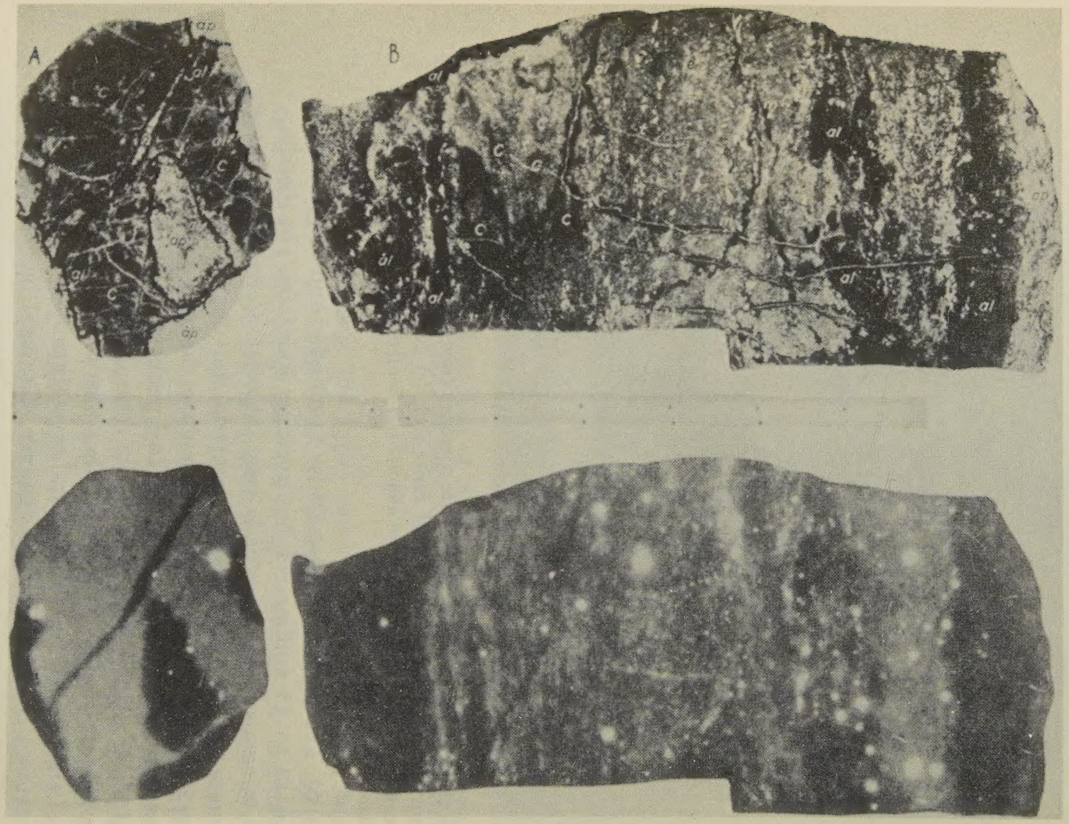

FIGURE 5. Photographs and radiographs of cerite specimens.

A. Specimen from northwestern deposit of northern group showing irregular veinlets of cerite rock (c) cutting aplite (ap) and bordered by irregular bands of allanite (al). Veinlet of allanite contains some quartz (q). Arrows point to grains of uraninite which produce large white spots in the radiograph.

B. Specimen from the southern deposit showing the full width of the vein and the complex mixture of rare-earth minerals: cerite (c); törnebohmite (t); monazite (m); brown epidote (e); allanite (al); bounded by aplite (ap). In the radiograph the white spots are due to uraninite.

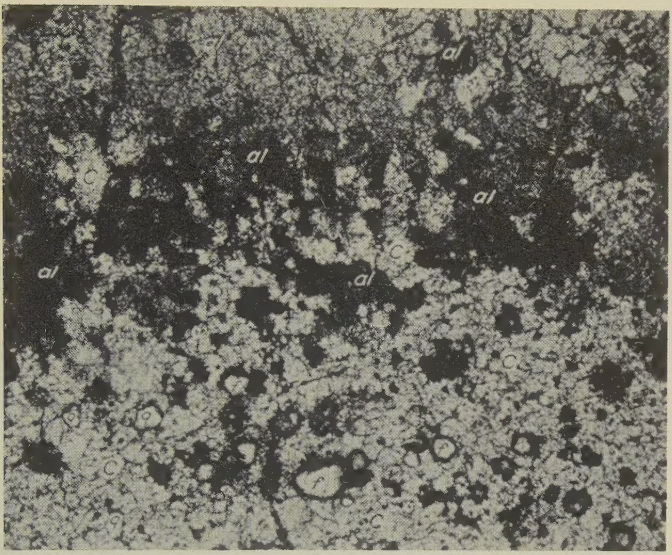

FIG. 6. (125×) Photomicrograph of cerite rock from northeastern deposit of northern group, showing the very irregular contact of the cerite material with allanite, which grades from brown at the border to green in the interior. Mixture of cerite and brown epidote (c); purple fluorite (f); quartz (q); allanite (al).

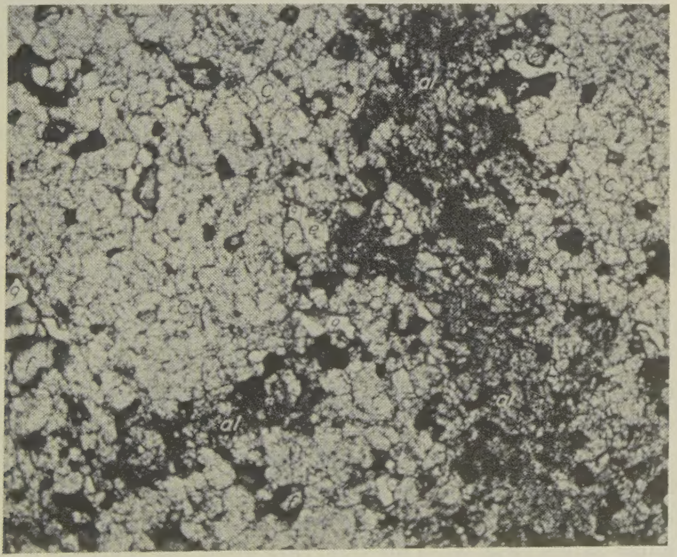

FIG. 7. (125×) Photomicrograph of cerite rock from northwestern deposit of northern group, showing veinlets of allanite (al) cutting the cerite material. Rounded grains of purple fluorite (f), brown epidote (e), and quartz (q) are scattered through the cerite (c).

In the northwestern deposit of the northern group the minerals are similar to those just described, but the cerite rock has a brownish cast, and the lenticular masses tend to be more irregular. Microscopic examination shows that much of the brown epidote, fluorite, and quartz is segregated into small rounded groups, surrounded by cerite (Fig. 7), but some of the grains of fluorite are concentrated along fractures in the cerite, like beads on a string, and some of the brown epidote occurs in irregular bands that seem to be replacing the cerite. Relatively straight veinlets of allanite cut the cerite rock in places. The larger ones, as shown in Fig. 5, contain a central seam of quartz.

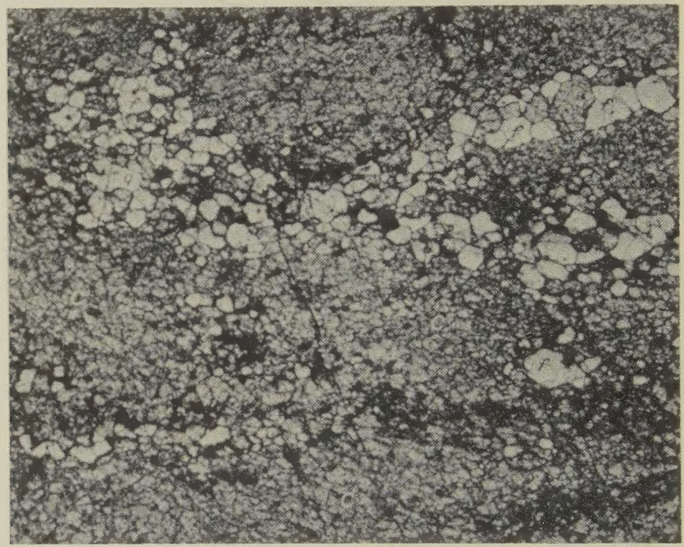

FIG. 8. (35×) Photomicrograph of cerite rock from southern deposit of northern group showing the schistose structure which suggests replacement of schist by the cerite. Mixture of cerite and brown epidote (c); purple fluorite (f); quartz (q).

The southern deposit of the northern group is in the schist a few feet from its contact with the Silver Plume granite, and the lenses of cerite rock are parallel to the foliation of the schist. The cerite and brown epidote are rather evenly distributed, but the fluorite is entirely absent in places and abundant in others. In one lens of cerite rock the grains tend to be elongated parallel to the foliation of the enclosing schist, and the fluorite and some of the coarser brown epidote grains are concentrated in irregular bands (Fig. 8). This structure gives the material a schistose appearance and suggests a replacement of the schist by the cerite.

Southern Group.—The most varied mineral assemblage is found in the southern deposit, 3,600 feet south of the northern group (Figs. 2 and 3). The lenticular vein here is about 8 inches wide and is bordered by aplite on one side and by aplite grading into schist on the other. As shown in Fig. 5, the vein consists of a rather complex mixture of rare-earth minerals bordered by irregular bands of allanite one-half to one inch wide. These minerals were apparently deposited in a definite sequence, each irregularly replacing parts of the earlier minerals. Lavender colored cerite was apparently the first mineral to be deposited. Cerite may have originally occupied the whole vein, but it is now confined to a band 1 inch to $1\frac{1}{2}$ inches wide on the western side of the vein (Fig. 5).

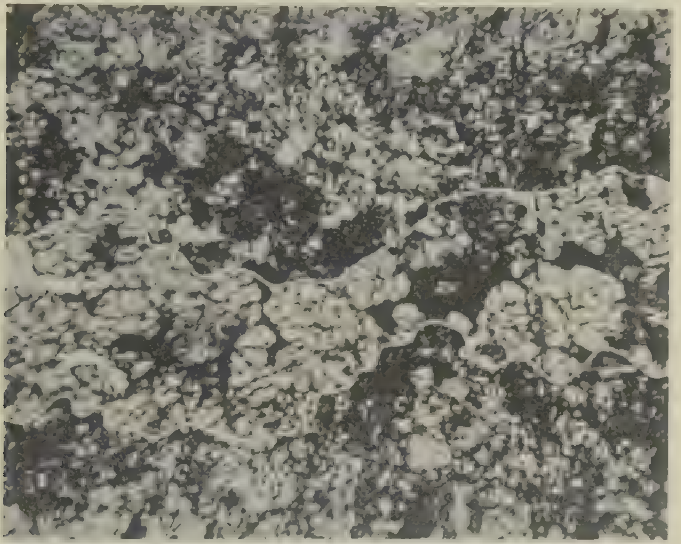

FIG. 9. (66×) Photomicrograph of cerite specimen from southern deposit showing irregular seam of törnebohmite (t), with some quartz (q) and pyrite (py) cutting cerite (c).

The cerite has been extensively replaced by greenish-gray törnebohmite, which now occupies most of the vein. This mineral is scattered through the cerite in irregular veinlets and masses, as shown in Fig. 9. The veinlets and the long direction of the crystals are roughly parallel to the walls of the vein as shown in Fig. 5.

Following the monazite, jet-black allanite extensively replaced törnebohmite, cerite and the aplite on either side of the vein as shown in Fig. 5. These bands of allanite are made up of large irregular grains 2 to 4 millimeters in diameter. Near the western side of the vein, a fairly regular veinlet of allanite and quartz 1 to 2 millimeters wide cuts through the cerite and törnebohmite. Figure 10 shows a photomicrograph of the

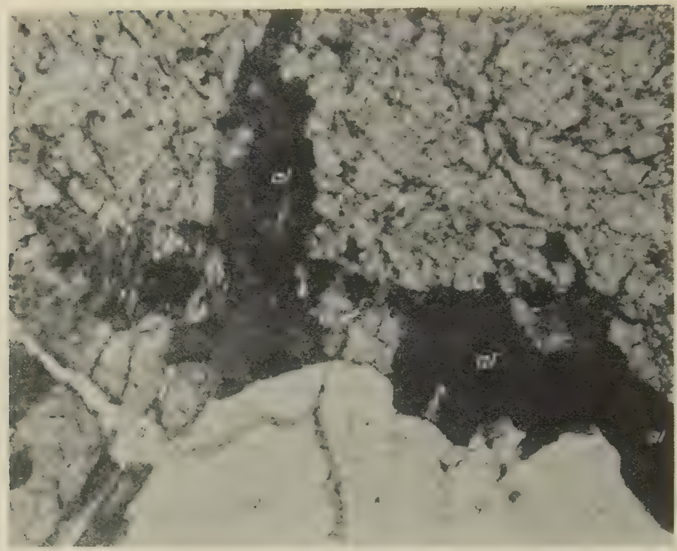

FIG. 10. (125×) Photomicrograph of cerite specimen from southern deposit, showing the border of a large veinlet of allanite (al), and quartz (q) that cuts through the cerite (c). Arrows point to minute spots of uraninite.

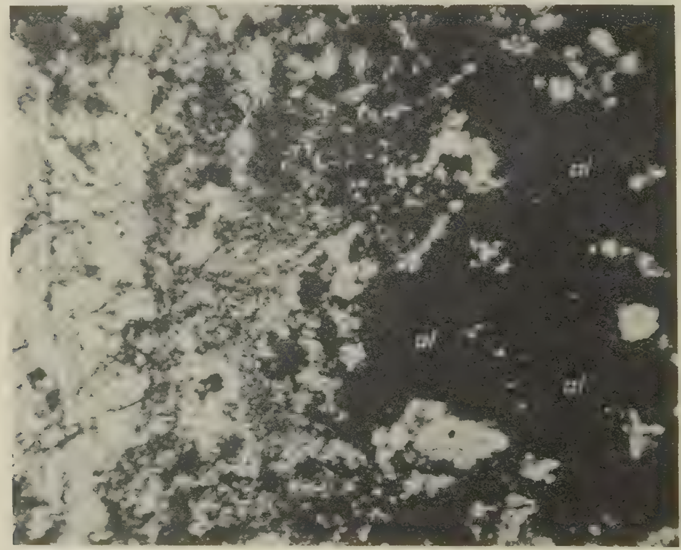

FIG. 11. (125×) Photomicrograph of cerite specimen from southern deposit showing allanite (al) irregularly replacing törnebohmite (t), and a seam of monazite (m) cutting the törnebohmite.

contact of this seam with the cerite, and illustrates how the allanite crystals finger out into the cerite. Most of the quartz appears to be contemporaneous with the allanite, but in one place a veinlet of quartz cuts the allanite (Fig. 10). In other places, masses of allanite irregularly replace cerite and törnebohmite as shown in Fig. 11.

Near the center of the vein the törnebohmite is cut by jagged veinlets of reddish-brown monazite. Although the veinlets are very irregular, the contact with the törnebohmite as seen in thin section is sharp (Fig. 11). A brown epidote which is scattered throughout the vein in small irregular discontinuous veinlets and lenses is later than the black allanite (Fig. 5). In places it cuts across veinlets and masses of the black allanite. It seems to be identical with the brown epidote of the northern group of deposits, but there the epidote is earlier than the allanite.

List of Minerals

The minerals of cerium and other rare-earths present in the Jamestown deposits are cerite, allanite, brown epidote, törnebohmite, bastnäsite, and monazite. The distribution of these and associated minerals in the two areas is as follows:

Northern deposit	*Southern deposit*
Cerite	Cerite
Allanite	Allanite
Brown epidote	Brown epidote
—	Törnebohmite
Fluorite	—
Bastnäsite	Bastnäsite
—	Monazite
Uraninite	Uraninite
Pyrite	Pyrite
—	Chalcopyrite
Quartz	Quartz

In addition to the mineralogical associations discussed under the section on occurrence, a more detailed mineralogical description is given on the following pages.

Cerite

The cerite occurs as small grains (about .2 mm.), gray to pinkish brown, some grayish lavender in color, in the aggregate already described. Under the microscope cerite shows faint pleochroism, colorless to pale pink. The birefringence is low. The character is positive, $2V=0°$ to $8°$. The indices of refraction are, $\alpha=1.815$, $\beta=1.815$, $\gamma=1.820$. The cerite grains in plain transmitted light resemble the brown epidote, but under crossed nicols the latter show high interference colors.

The cerite rock analyzed (Table 1) consisted of about three-fourths

TABLE 1. CHEMICAL ANALYSIS OF GRAY CERITE ROCK, A FINE-GRAINED MIXTURE OF CERITE, BROWN EPIDOTE, FLUORITE, BASTNÄSITE, AND SOME QUARTZ, FROM EASTERN DEPOSIT OF NORTHERN GROUP, NEAR JAMESTOWN, COLORADO.

[J. G. Fairchild, analyst]

	Per cent
SiO_2	18.78
Al_2O_3, TiO_2	0.24
FeO	1.17
U_3O_8	0.51 (U = .44)
Ce_2O_3	28.85
$(La, Tb)_2O_3$, etc.*	27.20
Y_2O_3, etc.	2.94
ThO_2	0.28 (Th = .25)
MnO	0.17
ZnO	None
CaO	12.55
MgO	0.16
PbO	0.07 (Pb = .07)
H_2O	0.96
CO_2	1.00
P_2O_5	None
F	5.94
Cl	None
B_2O_3, BeO	None
	100.82
Less O = F	2.52
	98.30

Sp. Gr. = 4.653

Pb: (U plus .36 Th) = .132 ± 1/5

Age = 940 million years ± 1/5 by logarithmic formula

* Neodymium and praseodymium were identified by absorption spectra.

cerite, with smaller quantities of fluorite, quartz, uraninite, and bastnäsite. Relegating the CO_2 to bastnäsite with the formula $(CeF)CO_3$, the remaining fluorine to fluorite, the $U_3O_8 + ThO_2 + PbO$ to uraninite, and assuming 5 per cent of quartz, the sample analyzed had the following mineral composition:

Cerite	76.1
Fluorite	11.3
Bastnäsite	5.0
Quartz	5.0
Uraninite	0.9
	98.3
All others	1.7
	100.0

Under "all others" are grouped the small quantities of Al_2O_3, TiO_2, FeO, MnO, and MgO. The assumption of 5 per cent of quartz is not based on any determination other than a rough estimate of grains in thin section. The calculation of the formula of cerite as shown in Table 2 suggests that this figure may be too high.

When the associated minerals are deducted and the remainder calculated to 100 per cent, the composition of the cerite is as shown in the last column of Table 2.

Table 2. Calculated Analysis of Pure Cerite

Analysis		Interpretation					Cerite Recalculated to 100 Per cent
		0.86% uraninite	5.00% bastnäsite	5.00% quartz	11.32% fluorite	76.14% cerite	
SiO_2	18.78	—	—	5.00	—	13.78	18.10
Al_2O_3, TiO_2	0.24	—	—	—	—	0.24	0.32
FeO	1.17	—	—	—	—	1.17	1.54
U_3O_8	0.51	0.51	—	—	—	—	—
Ce_2O_3	28.85	—	3.75	—	—	25.10	32.97
La_2O_3[a]	27.20	—	—	—	—	27.20	35.72
Y_2O_3	2.94	—	—	—	—	2.94	3.86
ThO_2	0.28	0.28	—	—	—	—	—
MnO	0.17	—	—	—	—	0.17	0.22
CaO	12.55	—	—	—	8.13	4.42	5.80
MgO	0.16	—	—	—	—	0.16	0.21
PbO	0.07	0.07	—	—	—	—	—
H_2O	0.96	—	—	—	—	0.96	1.26
CO_2	1.00	—	1.00	—	—	—	—
F	5.94	—	0.43	—	5.51	—	—
	100.82						100.00
	−2.52						
	98.30						

[a] Molecular weight taken is 331.

The recalculated analysis of the mineral cerite agrees closely with the published analyses. Small quantities of FeO (maximum 4.98 per cent), Al_2O_3 (maximum 2.64 per cent), and other constituents, are given in the analyses of cerite from Sweden. These older analyses report several per cent of water (maximum 8.10 per cent), and the formula of the mineral is generally written with considerable H_2O. The analysis of cerite from Colorado, with only about one per cent of H_2O, suggests, however, that the much greater content of water in the older analyses is due to alteration and is not inherent in the mineral. This conclusion is verified by Silberminz's[3] analysis of cerite from the Urals with only 1.29 per cent H_2O+ and 0.19 per cent H_2O-.

The content of CaO in ten analyses[4] of cerite varies considerably from none reported in two analyses from Sweden to a maximum of nearly 6 per cent in the cerite from Colorado. The figures reported are: 1.23, 1.27 (Urals); 1.31 (given as 1.35 by Dana), 1.65, 1.69, 3.56, 4.35, 5.80 (Colorado). The new mineral, lessingite, described by Silberminz, has 11.71 per cent CaO.

The recalculated analysis of the cerite from Colorado gives the following ratios:

SiO_2	.301 or 3
R_2O_3	.229 or 2
CaO	.103 or 1
H_2O	.070 or 1

yielding approximately the formula $CaO.2R_2O_3.3SiO_2.H_2O$. The mineral from Colorado is halfway between a calcium-free cerite and lessingite in composition, based on the content of CaO.

If the formula of calcium-free cerite is written $2R_2O_3.3SiO_2.H_2O$ (assuming that most of the water reported in the old analyses is due to alteration), then an apparent series exists:

CaO-free cerite	$2R_2O_3.3SiO_2.H_2O$
Cerite from Colorado	$CaO.2R_2O_3.3SiO_2.H_2O$
Lessingite	$2CaO.2R_2O_3.3SiO_2.H_2O$

Geijer[5] writes the formula of cerite as $2(Ca,Fe)O.3Ce_2O_3.6SiO_2.3H_2O$ which, when divided by two, becomes $(Ca,Fe)O.1\frac{1}{2}Ce_2O_3.3SiO_2.1\frac{1}{2}H_2O$, which is close to the formula of the cerite from Colorado.

In discussing the formula of allanite, Machatschki[6] groups the Ca and Ce together in his X-group and the varying content of CaO in analyses of cerite suggests that perhaps the CaO should not be separately considered but should be placed with the cerium and other rare earths.

The atomic ratios calculated from the recalculated analysis of the cerite from Colorado are:

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[3] Silberminz, V., *Comp. Rend. Acad. Sci., U. S. S. R.*, A, No. **2,** 55, (1929); *N. Jahrb. Min.*, **1,** 123 (1930).

[4] Eight analyses of cerite from Sweden listed in Doelter's *Handbuch der Mineralchemie*, **2,** pt. 2, 166–167 (1915), the one from the Urals by Silberminz, and the one from Colorado.

[5] Geijer, Per, The cerium minerals of Bastnäs at Riddarhyttan: *Sveriges Geol. Undersökning*, Arsbok, **14** (1920), no. 6, 15 (1921).

[6] Machatschki, Felix, Die kristallochemischen Beziehungen zwischen Epidot-Zoisit und Orthit-Allanit: *Centralbl. Min., Geol., u. Pal.*, Abth. A, 89–96; 154–158 (**1930**).

$$
\begin{array}{lr}
\text{Si} & 301
\end{array}
\qquad z = 301 = 1 \times 301
$$

$$
\left.\begin{array}{lr}
\text{Ce} & 208\\
\text{La} & 216\\
\text{Y} & 34\\
\text{Ca} & 103\\
\text{Fe} & 21\\
\text{Mn} & 3\\
\text{Mg} & 5
\end{array}\right\}
\qquad 590\ X = 590 = 2 \times 295
$$

$$
\left.\begin{array}{lr}
\text{O} & 1421\\
\text{(OH)} & 140
\end{array}\right\}
\qquad 1561 = 5 \times 312
$$

The formula of cerite may then be written $X_2Y_0z_1(O,OH)_5$, with X = rare earths, Ca, Fe, Mn, Mg; or, for a calcium and water-free cerite, Ce_2SiO_5 or $Ce_2O_3 . SiO_2$.

The cerite from Colorado agrees with the cerite from Sweden in its optical properties. Lessingite apparently has different optical properties. While the cerite from Colorado is apparently the calcium-richest cerite and thus approaches lessingite in composition, the optical properties place it with cerite rather than lessingite as shown in Table 3.

TABLE 3. COMPARISON OF OPTICAL PROPERTIES OF CERITE

Cerite Colorado Glass	Cerite Sweden		Cerite Urals Silberminz	Lessingite Urals Silberminz
	Geijer	Larsen		
$\alpha = 1.815$		1.817	1.810	—
$\beta = 1.815$	1.81	1.818	—	—
$\gamma = 1.820$		1.821	1.825	1.785
B = .005	.002	.004	.015	.006
Sign +	+	+	+	−
2V = 0° to 8°	0° to very small	25°	11°	44°

Allanite

Allanite, a rare-earth epidote, sometimes called orthite, is one of the more common minerals in the cerite assemblage, and apparently replaces the cerite. Allanite, in the veins of the southern deposit, occurs in bladed or tabular crystals up to 2 millimeters wide and 5 millimeters long. A few crystals of megascopic size have been observed in the northern deposit. The allanite is jet black and brittle with no distinct cleavage.

Under the microscope, however, the optical properties of allanite from the two localities are different. That from the southern deposit shows much stronger pleochroism and higher indices of refraction than that from the northern deposit. The pleochroism is: X, yellowish green, Y and Z, pinkish to reddish brown. Absorption strong, Y and Z>X. Indices of refraction: Allanite, northern deposit, $\alpha=1.758$, $\beta=1.765$, $\gamma=1.785$; positive; axial angle small, $2V=30°$. Allanite, southern deposit, $\alpha=1.788$, $\beta=1.810$, $\gamma=1.820$; negative; $2V=25°$ to $30°$.

The allanite from the southern deposit, which has unusually high indices of refraction and shows unusually strong pleochroism for this mineral, was analyzed by Charles Milton of the Geological Survey. The results given in Table 4 are comparable to the analyses of allanite given by Dana,[6a] except for the presence of titanium, a low aluminum content, and high ferric iron and cerium contents. Of the 40 analyses given by Dana, none show any titanium, only 3 show less than 10.25 per cent Al_2O_3, and the alumina content of most of them ranges from 13 to 17 per cent. Only two of the analyses listed by Dana have a higher ferric iron oxide content than 10.33 per cent, and the majority range from 3 to 6 per cent. Only two of the listed analyses show more than 14.61 per cent Ce_2O_3, and most of them show a range of from 4 to 7 per cent. The 10.32 per cent of "other rare earths" in Milton's analysis is probably made up mostly of didymium and lanthanum. The listed analyses show from 2.71 to 23.98 per cent Di_2O_3 and from 0 to 8.10 per cent La_2O_3, whereas the Y_2O_3 and Er_2O_3 contents range only from 0 to 2.92 per cent and from 0 to 2.00 per cent, respectively. Milton's analysis also serves to check the

TABLE 4.—CHEMICAL ANALYSIS OF ALLANITE FROM SOUTHERN CERITE DEPOSIT, NEAR JAMESTOWN, COLORADO.

[Charles Milton, analyst]

	per cent
SiO_2	30.40
Al_2O_3	10.25
Fe_2O_3	10.33
FeO	10.29
MgO	1.44
CaO	7.47
Na_2O	0.02
K_2O	0.16
H_2O	1.95
TiO_2	1.46
MnO	0.66
Ce_2O_3	14.61
Other rare earths	10.32
ThO_2	none
PbO	none
	99.36

[6a] Dana, E. S., *System of Mineralogy*, 6th Ed., 524 (1909).

radiographs in showing that neither thorium nor lead is present, although about half of the listed analyses show the presence of thorium, ranging from 0.18 to 3.48 per cent ThO_2.

Treating the analysis as was done by Machatschki[7] for other allanites (Table 5), the analysis agrees fairly well with his formula $X_2Y_3z_3(O,OH,F)_{13}$ where

X = Ca, Ce, and other rare earths, Mn, K, Na
Y = Al, Fe''', Fe'', Mg, Ti
z = Si

TABLE 5. ATOMIC RATIOS OF ANALYSIS OF ALLANITE

Si	506		$z=506=3\times169$
Al	201	527	$Y=527=3\times176$
Fe'''	129		
Fe''	143		
Mg	36		
Ti	18		
K+Na	4	298	$X=298=2\times149$
Ca	133		
Mn	9		
Ce	89		
R.E.[a]	63		
(OH)	216	2,311	$2,311=13\times178$
O	2,095		

[a] Molecular weight of $(\text{Rare earths})_2O_3$ taken as 330.
Machatschki's formula $= X_2Y_3z_3(O, OH, F)_{13}$
Formula from Milton's analysis $= X_{1.79}Y_{3.17}z_{3.04}(O,OH)_{13.88}$

Brown epidote

Brown epidote is a common constituent of the cerite rock in both the northern and southern deposits. It occurs as disseminated grains and as individual bladed crystals, some of which are 0.15 to 0.35 millimeter in size.

In thin section the brown epidote is pale yellowish-brown and shows brilliant interference colors. It is optically positive, 2V variable, small to medium. Pleochroic colors, yellow and brown. The indices of refraction are: $\alpha=1.748$, $\beta=1.753$, $\gamma=1.765$.

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[7] Machatschki, Felix, Die kristallochemischen Beziehungen zwischen Epidot-Zoisit und Orthit-Allanit: *Centralbl. Mineral, Geol., u. Pal.*, Abth. A, 89-96; 154–158 (1930).

Törnebohmite

Törnebohmite, a monoclinic hydro-fluo-silicate of the cerium metals and aluminum, occurs as roughly rectangular grains about .16 by .48 mm., replacing cerite. In thin section törnebohmite shows distinct pleochroism, pink or yellow to blue-green. Both the refringence and birefringence are high. Optically positive, $2V=20°$ to $30°$. Dispersion distinct, $r<v$. Indices of refraction are: $\alpha=1.808$, $\beta=1.812$, $\gamma=1.838$.

Fluorite

The widespread deep violet fluorite was first thought to be yttrocerite[8] as the determined index of refraction (1.435) agrees with the index of 1.434 given by Larsen and Berman[9] for yttrocerite. The specific gravity of this fluorite seemed greater than 3.3, and hence apparently too high for fluorite. This apparent greater specific gravity, however, is more probably due to the minute inclusions of uraninite and cerite. A consideration of the index values given for the fluoride of the rare earths (fluocerite—or better, tysonite) with those of calcium fluorides containing rare-earth fluorides, indicates that the index of refraction given by Larsen and Berman for yttrocerite cannot be correct and that the material on which the determination was made must have been wrongly labelled and was fluorite and not yttrocerite.

The mean index of tysonite, rare-earth fluoride, is about 1.61. Hence the introduction of a small quantity of rare-earth fluorides into fluorite, with index of 1.434, raises the index considerably, as for example, in yttrofluorite whose index is given as 1.457±. Therefore the Jamestown mineral with an index of 1.435 must be fluorite.

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[8] The names yttrocerite and fluocerite are very misleading. Neither mineral is cerite with yttrium or fluorine respectively, as the name would indicate. Yttrocalcite similarly is not calcite containing yttrium. As Winchell (*Elements of Optical Mineralogy*, 3d ed., **1933**, p. 35) states: "Fluorite can take into crystal solution up to 50 per cent YF_3 and the mix-crystals are called *yttrofluorite*. It can take into crystal solution up to 55 per cent CeF_3 and the mix-crystals are called *cerfluorite* (unknown in nature). Mix-crystals of yttrofluorite and cerfluorite are known in nature; they are called yttrocerite." The name yttrocerite should be discarded as misleading. Depending on whether yttrium or the cerium metals are dominant, the so-called yttrocerite should be named either yttrofluorite or cerfluorite. Geijer (On fluocerite and tysonite: *Geolog. Förening. Förhandl.*, **43** (no. 344), 19–23, 1922) shows that "the fluocerite and the tysonite are one and the same mineral species with the formula $(Ce, La, Di)F_3$," and on the basis of priority prefers fluocerite. As this name is so misleading, it seems preferable to use the name tysonite.

[9] Larsen, E. S., and Berman, Harry, The Microscopic Determination of the Nonopaque Minerals: *U. S. Geol. Survey, Bull.* **848,** 47, (1934).

Bastnäsite

Bastnäsite, a fluocarbonate of cerium, with the formula $(CeF)CO_3$, was identified in a few of the coarser cerite specimens from Colorado, but it probably is present in all of the specimens. As Geijer[10] states for the cerite from Sweden, "There is, in fact, hardly one thin section with any notable percentage of cerite that does not also contain bastnäsite, often making up one third or more of the cerite ore." The powdered cerite rock effervesces slightly when treated with HCl, nearly every grain of material slowly evolving bubbles of CO_2 so that large aggregates of the powder, covered and permeated with minute bubbles, will float for some time in the acid. The effervescence is very different from that given by calcite, as shown by tests on material to which a little calcite was added. No calcite or analogous carbonate was seen in thin sections in any of the cerite rock from Colorado. In the interpretation of the analysis of the cerite rock, the CO_2 is allocated to bastnäsite.

A few isolated grains of bastnäsite gave the following optical properties: Uniaxial positive; $\omega = 1.716$, $\epsilon = 1.817$. The color is reddish brown, and the grains resemble monazite.

Monazite

Veinlets of reddish-brown monazite are found near the center of the veins of törnebohmite, and lenticular areas and grains of monazite are scattered through other parts of the vein.

Monazite is a monoclinic phosphate of the cerium metals. In thin section it is pale reddish-brown and shows high interference colors. The monazite is optically positive, $2V = 10°$ to $15°$. Dispersion moderate, $r > v$. The indices of refraction are, $\alpha = 1.790$, $\beta = 1.791$, $\gamma = 1.840$.

Uraninite

Small rounded grains of uraninite, identified by their radioactivity, are scattered throughout the veins, and appear to be later than all the other rare-earth minerals, as they are localized in places along late fractures. These grains show a dull black, faintly metallic luster as compared with the glossy, jet-black color of the allanite. Their distribution is shown in the radioactive photographs of Fig. 5. Some of the grains are as much as 1.5 millimeters in diameter, but most of them are of microscopic size (Fig. 10). These grains were identified as uraninite by comparing the intensity of their radioactivity with that of specimens of known uraninite.

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[10] Geijer, Per, *Loc. cit.*

Sulphides

Pyrite and minor amounts of chalcopyrite are scattered throughout the vein in small grains and irregular veinlets, and appear to be the latest minerals deposited. They range in size from microscopic grains to masses and veinlets 2 millimeters wide. The veinlets cut through all the rare-earth minerals including the uraninite.

COMPARISONS WITH OTHER DEPOSITS OF CERITE

In central Sweden the two known deposits of cerite are about 30 km. apart. At the original locality[11] at Bastnäs in the Riddarhyttan district, province of Västmanland, where cerium was discovered in 1804, cerite has been identified at two mines. It occurs in leptites and mica schists with subordinate limestone-dolomite bands. The cerium minerals form narrow bands in the silicate zones (skarn) of quartz-banded hematite. These narrow bands are fine-grained aggregates of cerite, fluocerite, allanite, törnebohmite, and other minerals.

In the Östanmossa mine,[12] Norberg, N.E. of the Riddarhyttan district, cerite occurs with allanite, a magnesium allanite, and other non-cerium minerals, in a silicate skarn in granular magnetite replacing dolomite near a granitic contact. While present in some abundance, the cerite usually is only in microscopic grains.

In Russia, in the Kyshtymsk district in the Urals,[13] cerite with törnebohmite, lessingite, and bastnäsite, was found in pebbles in auriferous alluvials, derived from a contact zone of alkali granites.

Cerite is mentioned,[14] without description, as having been identified in the pegmatite in which the well known Villeneuve mine is situated, in Papineau County, Quebec, Canada. This pegmatite contains microcline, albite, muscovite, lepidolite, uraninite, monazite, purple fluorite, and many of the usual accessory pegmatite minerals. The occurrence in Colorado—in pegmatite and aplite—along the contact of granite and schist inclusions seems to be more closely related to the type of occurrence in Canada than the European occurrences, though here too contact metamorphism has played a role.

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[11] Geijer, Per, The cerium minerals of Bastnäs at Riddarhyttan: *Severiges Geol. Undersokning*, **1921**, Arsbok 14 (for 1920), No. 6, 24 pp., Abs. in *Mineral. Abs.*, **1**, 251 (1921).

[12] Geijer, Per, Some mineral associations from the Norberg district: *Sveriges Geol. Undersökning*, **1927**, Arsbok 20 (for 1926), No. **4**, 32 pp., Abs. in *Mineral. Abs.*, **3**, 273–274 (1927).

[13] Silberminz, V., Sur le gisement de cerite, de bastnäsite et d'un mineral nouveau, la lessingite, dans le district minier de Kychtym (Oural): Abs. in *Mineral. Abs.*, **4**, 150–151 (1929).

[14] Ellsworth, H. V., Rare element minerals of Canada: *Canada Geol. Survey*, *Econ. Geol. Survey*, No. **11**, 241 (1932).

The mineral associations in these five occurrences are listed in Table 6.

TABLE 6. MINERALS ASSOCIATED WITH CERITE

Sweden		Russia	Canada	Colorado
Bastnäs	Norberg			
Cerite	Cerite	Cerite	Cerite	Cerite
—	—	Lessingite	—	—
Allanite	Allanite	—	—	Allanite
—	Mg-Allanite	—	—	Brown epidote
Törnebohmite	—	Törnebohmite	—	Törnebohmite
Fluocerite (Tysonite)	—	—	Fluorite	Fluorite
Bastnäsite	—	Bastnäsite	—	Bastnäsite
—	—	—	Monazite	Monazite
—	—	—	Uraninite Gummite	Uraninite
Lanthanite	—	—	—	—
Actinolite	Actinolite Tremolite	—	Common pegmatite minerals	Common pegmatite minerals
—	Diopside	—	—	—
—	Chondrodite Norbergite	—	—	—
—	Garnet	—	Garnet	—
Quartz	—	—	Quartz	Quartz
—	—	—	Tourmaline	—
—	—	—	Beryl	—
—	—	—	Apatite	—
—	—	—	Zircon	—
Magnetite (rare)	—	—	—	—
Chalcopyrite	—	—	—	Pyrite Chalcopyrite
Bismuthinite	—	—	—	—
Molybdenite	—	—	—	—
Linnaeite (rare)	—	—	—	—

RADIOACTIVITY

Specimens from each of the deposits were sawed in two and placed for 6 days on photographic plates, with black paper between. The results show that in the northern group of deposits the gray and brownish-gray mixture of cerite, brown epidote, and purple fluorite shows weak but distinct radioactivity, but the spots of strongly active uraninite stand out in prominent contrast (Fig. 5). The clove-brown cerite material is only very slightly radioactive and the allanite shows little or no radioactivity on short-period exposure.

In the large specimen from the southern deposit, it is difficult to interpret the results because the uraninite is so intimately and finely disseminated through the vein that it is impossible to tell how much of the radioactivity is due to the other rare-earth minerals present. However, it appears that the törnebohmite, brown epidote, and the monazite all show a weak radioactive response, the lavender cerite shows very weak activity, and the black allanite shows practically none. The larger grains of uraninite show up prominently against the background of the other minerals.

Age Determination

On the basis of its lead-uranium ratio, the calculated age of the gray cerite material is 940,000,000 years. However, owing to the small percentages of uranium and lead present, the range of probable error is large and is estimated by A. C. Lane[15] to be about 20 per cent. In spite of this large range, the analysis serves to place the cerite deposits and the Silver Plume granite to which they are related in the middle pre-Cambrian, and makes them younger than the Pikes Peak granite, whose determined age is one billion years.[16] This relation is substantiated by the field evidence, for throughout the Front Range the Silver Plume granite is found to be younger than the Pikes Peak granite.[17]

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[15] Lane, A. C., Report of the Committee on the Measurement of Geologic Time, Division of Geology and Geography, *National Research Council*, 69, (**1935**).

[16] Physics of the Earth, vol. **4**, Age of the Earth, *Bull. Nat. Res. Council*, **90**, 338 (1931).

[17] Spurr, J. E., Garrey, George H., and Ball, S. H., Economic geology of the Georgetown quadrangle, Colorado: *U. S. Geol. Survey*, *Prof. Paper* **63**, 59–60 (1908).

THE STRUCTURAL SCHEME OF ATTAPULGITE*

W. F. Bradley**

The name attapulgite was applied in 1935 by J. De Lapparent[1] to a clay mineral which he encountered in fuller's earths from Attapulgus, Georgia, and Mormoiron, France. Objections have been raised, and these objections were recently reviewed by De Lapparent,[2] that the material involved does not justify the application of a mineral name. However, no attempt has been made to study the crystal structure. De Lapparent himself has suggested for classification purposes that attapulgite is a layer silicate related to the micas, but some obvious inconsistencies with the *x*-ray powder diffraction patterns of the mineral have suggested the desirability of attempting a better explanation. The material used in this investigation was obtained from the Attapulgus Clay Co., Attapulgus, Ga. The raw clay was dispersed and freed of large crystalline impurities by sedimentation. Centrifuge fractions were then obtained, of which particularly the fraction between .1 and .05μ appeared homo-

Table 1. Chemical Analyses of Attapulgite

	A	B
SiO_2	53.64	55.03
TiO_2	0.60	n.d.
Al_2O_3	8.76	10.24
Fe_2O_3	3.36	3.53
FeO	0.23	n.d.
MnO	0.03	n.d.
MgO	9.05	10.49
CaO	2.02	—
Na_2O	0.83	n.d.
K_2O	0.75	0.47
P_2O_5	0.79	n.d.
H_2O+	10.89	10.13
H_2O-	9.12	9.73
Exchange capacity (me/100 gr.)	n.d.	21
Optical data		$\gamma=1.540$ $\gamma-\alpha=$ .032 (−); 2 V small

A. Analysis given by De Lapparent (op. cit.)

B. Analysis of clay fraction used for this study.

n.d. = not determined.

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* Published with the permission of the Chief, Illinois State Geological Survey, Urbana, Illinois.

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[1] An essential constituent of fuller's earth. *Compt. rend.* **201,** 481–483 (1935).

[2] Defense of attapulgite: *Bull. soc. fr. de Min.* **61,** 253–83 (1938).

geneous and showed no extraneous lines in its diffraction diagram. Flake-shaped aggregates of this material were employed in obtaining the subsequent data. The chemical analyses and optical data given in Table 1, and the powder diffraction diagram in Fig. 1 leave no doubt of the identity of this material with that originally described by De Lapparent.

"Fibre diagrams" of the above flaky aggregates immediately distinguish attapulgite from the common clay minerals with prominent basal cleavage. For the small values of sin θ the distribution of visually estimated diffracted intensity in a given ring tends to vary inversely with the angular displacement from the horizontal direction (zero layer line). Such a distribution results from the restriction of one axis (later chosen as c) of the individual crystallites to the plane of the flake. For the clays with basal cleavage, similarly prepared flakes consist of aggregates of particles each of whose basal planes lies in the plane of the flake.[3]

A series of diffraction patterns made with radiation incident at various inclinations to such flakes served to provide optimum conditions for the observation of interferences of the type $hk0$, and permitted the identification of about 15 such interferences. A few poorly defined arcs on residual first and second layer lines indicate a periodicity of about 5.2Å, along the third, or c, axis. Figure 1 includes three of the "fibre diagrams" at increasing angles of incidence. Figure 2 is a plot of observed values of sin θ up to .5 for the interferences which showed arcs across the equatorial layer line.

Too few interferences appear to attempt a complete solution of the structure, but many silicate structures are available from which reasonable analogies may be drawn. Figure 3 is a projection onto 001 of an idealized monoclinic structural scheme consistent with the diffraction data. The composition of this ideal cell is $(OH_2)_4(OH)_2Mg_5Si_8O_{20}.4H_2O$, in good agreement with the chemical analyses if trivalent cations are considered equivalent to 1.5 Mg^{++}. The dimensions of this section are $a_0 \sin \alpha = 12.9$Å, and $b_0 = 18$Å. There are two molecules in the unit cell and the space group is probably $C_{2h}^3 - C^2/m$. The silicate chains running parallel to c along $00z$ and $\frac{1}{2}\frac{1}{2}z$ are similar to amphibole chains. Oxygens at the corners of the chains link each to four neighbors. Chains of water molecules, also running parallel to c fill the interstices between amphibole chains, and this water represents that which is lost below 100°C. without material effect upon the diffraction patterns. An equal amount of water appears, coordinated about Mg, representing that less easily removed, and four OH groups per cell represent the water not driven off below 500 or 600°C.

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[3] Clark, G. L., Grim, R. E., and Bradley, W. F., Notes on the identification of minerals in clays by x-ray diffraction: *Zeits. Krist.* **96**, 322–324 (1937).

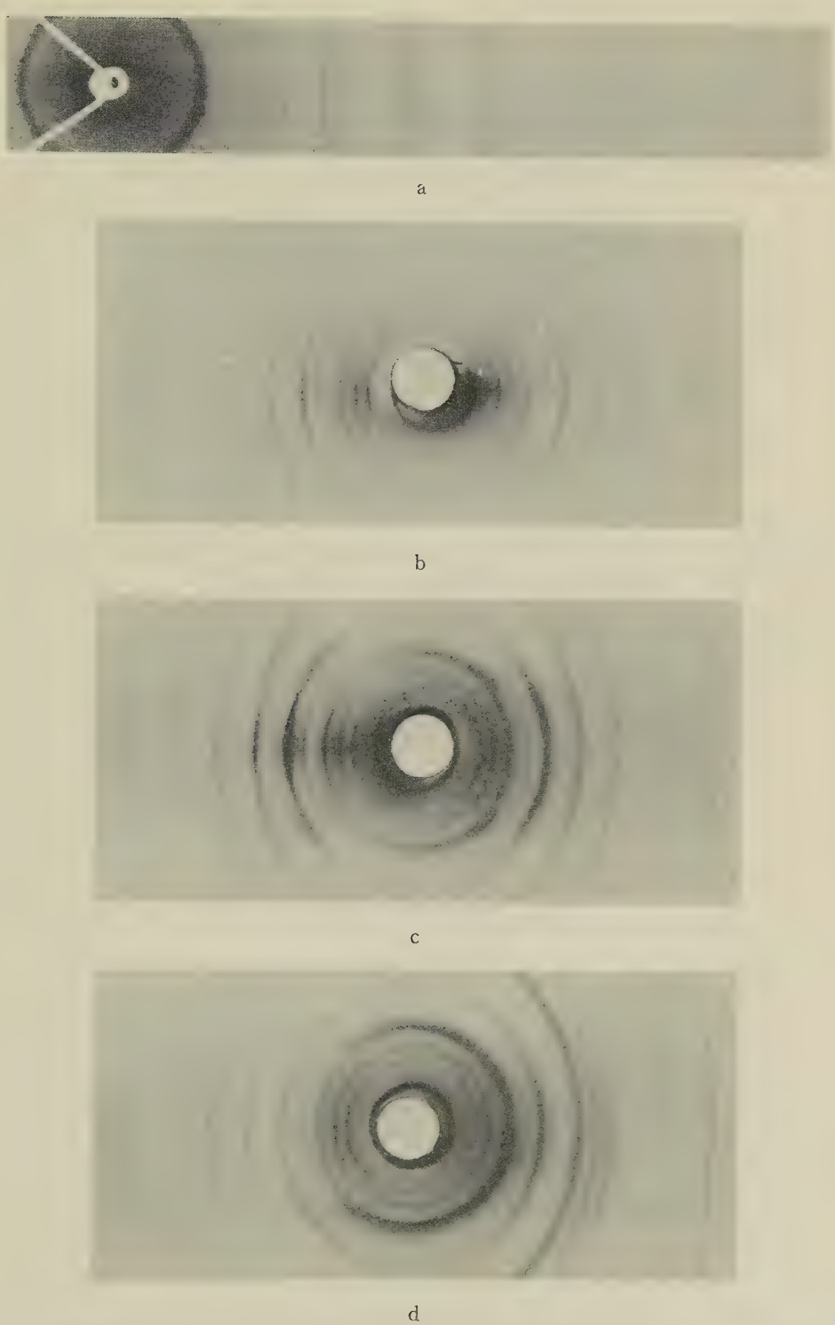

FIG. 1. Diffraction patterns of attapulgite. (a) powder, (b), (c) and (d) flakes inclined to beam at angles of 0, 15°, 35°. All patterns registered with Fe Kα radiation. Camera radius for (a) = 6.3 cm.; for (b), (c), and (d) = 2.8 cm.

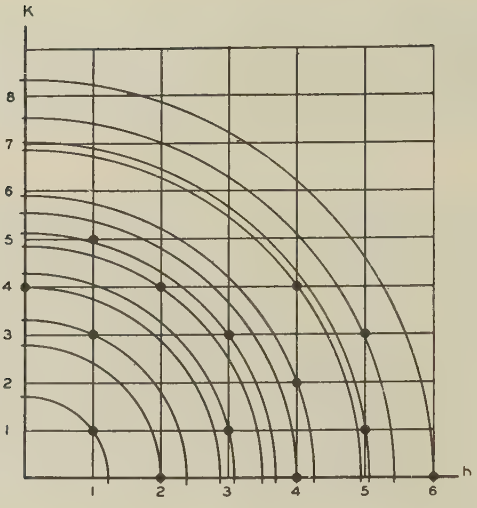

FIG. 2. Observed values of sin θ for the prismatic interferences of attapulgite plotted as radii of circles, indicating the corresponding indices.

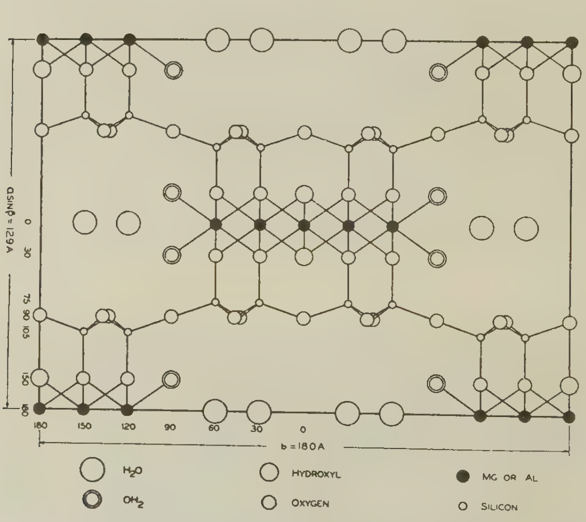

FIG. 3. Idealized proposed structure for attapulgite projected onto 001.

TABLE 2. ATOMIC COORDINATES IN ATTAPULGITE

	x	*y*	probable set of equivalent positions
4 OH	30	0	*i*
8 O_{I}	30	30	*j*
8 O_{II}	30	60	*j*
8 OH_2	30	90	*j*
4 O_{III}	90	0	*i*
4 O_{IV}	90	90	*f*
8 O_{V}	90	45	*j*
8 O_{VI}	90	45	*j*
4 H_2O_{I}	0	120	*h*
4 H_2O_{II}	0	150	*g*
2 Mg_{I}	0	0	*a*
4 Mg_{II}	0	30	*h*
4 Mg_{III}	0	60	*g*
8 Si_{I}	75	30	*j*
8 Si_{II}	75	60	*j*

TABLE 3. COMPARISON OF CALCULATED WITH OBSERVED INTENSITIES IN THE *hk*0 ZONE

Indices	d_{hkl} calc.	d_{hkl} obs.	$\frac{F^2\text{X Lorenz Factor}}{1000}$	Visually* Estimated Intensities
110	10.48	10.50	330	ss
200	6.45	6.44	17	ms
130	5.44	5.42	12	m
220	5.24	—	1	—
040	4.50	4.49	66	s
310	4.18	4.18	13	w
240	3.69	3.69	18	m
330	3.49	3.50	12	w
150	3.47		2	
400	3.23	3.23	120	ss
420	3.04	3.03	3	ww
350	2.76	—	2	—
440	2.62	2.61	43	s
510	2.56	2.55	8	w
530	2.38	2.38	5	w
080	2.25	—	1	—
600	2.15	2.15	15	m
550	2.10	—	1	—
480	1.845	—	1	—
390	1.815	1.82	3	ww
660	1.75	—	1	—
800	1.615	1.62	3	ww
680	1.555	1.56	17	w
0120	1.50	1.50	40	m

* ss = very strong, s = strong, ms = medium strong, m = medium, w = weak, ww = very weak —= not observed.

In Table 2 are listed ideal x and y coordinates for the cross section, and in Table 3 various calculated $hk0$ intensities are compared with those visually estimated on the films. In view of the meagre data available, and the uncertainties in the exact manner of isomorphous replacement, no attempt has been made to adjust coordinates for distortion of coordination polyhedra due to sharing. The excellent qualitative agreement noted seems sufficient to establish the gross features of the structure, and can probably even be said to lend some credence to such features as the distribution and status of the three sorts of water involved. A secondary tendency of the b-axes to lie near the plane of the flakes more often than perpendicular to them modifies the observed relative intensities somewhat, but can hardly invalidate the agreement shown.

Easy cleavage parallel to 110 is apparent from Fig. 3 and accounts for both the fibrous occurrence and the secondary orientation tendency mentioned above. The failure of the mineral to build longer chains, like tremolite or chrysotile, is probably related to the more variable chemical composition. The distribution of Al ions among the five available octahedral positions in a chain can be accommodated either by vacancies in the octahedral positions or by some replacement of Si by Al. Either process, however, should weaken the chains. It would appear doubtful if an Al end member could exist.

In several instances, optical examinations have led to the designation of attapulgite as montmorillonite. It is interesting to observe that a section through the above structure parallel to 010 presents the same sequence of layers of atoms as does a section of the montmorillonite structure parallel to c when one layer of water molecules is present.[4] Optical data are commonly obtained from oriented flakes similar to those used in these x-ray diffraction studies, and the respective orientations of attapulgite and montmorillonite flakes result in a similar disposition within the flakes of the directional properties of the crystallites which govern the optical characteristics. Optical data alone, therefore, can not be critical for distinction between the two minerals.

The inorganic base exchange capacity, which amounts to less than one ion per unit cell, probably involves exchange of ions associated with the water chains. The clay as examined in this study was ammonia saturated.

Note. Since the preparation of this manuscript it has come to the author's attention that in *Nature*, **142,** 114–115 (1938), G. Nagelschmidt has suggested the likelihood of just such a structural scheme as the above for attapulgite as well as for some other related minerals.

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[4] Bradley, W. F., Grim, R. E., and Clark, G. L., A study of the behavior of montmorillonite upon wetting: *Zeits. Krist.*, **97**, 216–222 (1937).

Hendricks, S. B., and Jefferson, M. E., Structures of kaolin and talc-pyrophyllite hydrates and their bearing on water sorption of the clays: *Am. Mineral.* **23,** 863–875 (1938).

MICROLITE AND STIBIOTANTALITE FROM TOPSHAM, MAINE

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In a paper by the senior author (1934) describing the minerals found in a topaz pegmatite in Topsham, there occurs the following statement: "In the pocket, gahnite is associated with albite. In the lower portions nearly every block of albite that was broken showed a band of scattered minute crystals of emerald-green gahnite about half an inch beneath the free surface of the block. They must have been deposited simultaneously for a very short time while the albite was still growing and when this zone was the surface zone. In vugs of the albite, octahedrons or flat distorted hexagonal plates of gahnite reach a maximum dimension of one inch."

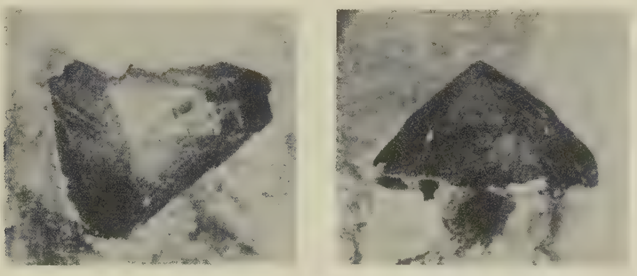

FIG. 1. Two views of a microlite crystal showing pseudohexagonal distortion.

The facts of this statement were correct except that the mineral reported as *gahnite* is now known to be *microlite*. The mistake was perhaps a natural one for large crystals of dark green gahnite had been found in the same quarry outside the pocket, and when these minute green octahedrons appeared they were assumed, without special examination, to be of the same species. In the course of a study of the Topsham mineral series made in the Harvard Mineralogical Laboratory by Mr. G. W. Stewart, it was found that this assumption was a mistake. Since microlite is a sufficiently rare mineral to deserve record whenever found, the analysis and description of this occurrence is here presented.

With few exceptions the Topsham microlite is green, a color not before recorded for this mineral. It varies from dull grass green in the larger crystals to vivid emerald green in the smaller transparent crystals. The dominant form of the crystals is octahedral with an occasional narrow face of the dodecahedron. There are, however, numerous extreme distortions which give the appearance of a hemimorphic hexagonal crystal. One of these was photographed and is shown in Fig. 1. The largest crystal is one half of an octahedron an inch on an edge; it is implanted on sericite with an irregular bounding surface.

The study of several hundred specimens from the pocket revealed the following associations of microlite:

1. Enclosed in albite as described in the quotation.
2. Minute crystals embedded in topaz crystals without apparent relation to crystal boundaries of the latter.
3. Enclosed in lepidolite crystals; always a single layer of minute octahedrons rather widely but regularly spaced and arranged parallel to three or more of the bounding pseudoprism faces of the mica.
4. In sharp crystals at a boundary between quartz and lepidolite.
5. Implanted on tourmaline needles.
6. Encrusted with stibiotantalite crystals—a single specimen of minute size.
7. Microlite is often coated with sericite.

All of these associations are in harmony with its having formed late in the period of pocket filling; all of the minerals listed were deposited on free surfaces towards the end of deposition. Where enclosed in another mineral it always appeared as if the microlite were deposited for a short time on a free surface to be afterwards covered over by later growth of the host mineral. There was no evidence that could be seen favoring deposition by replacement.

Since the high density of this microlite was the property which first led to its proper identification, special care was devoted to this determination. Table 1 contains the record of the observations made on selected fragments with the microbalance and reveals figures which are in part much higher than any hitherto reported. They are believed to be justified by the discussion of the *x*-ray study which follows.

TABLE 1. SPECIFIC GRAVITY OF MICROLITE

Observer	No. of Observations	Locality	Color	Specific Gravity
Berman	2	Topsham, Me.	green	6.41
Draisin	4	Topsham, Me.	green	6.42 ± .04
Draisin	6	Topsham, Me.	dark brown	6.36 ± .03
Draisin	3	Amelia Courthouse, Va.	amber yellow	6.05 ± .01
Draisin	3	Newry, Me.	pale yellow glassy	5.85 ± .12
Draisin	2	Embudo, N. Mex.	pale yellow glassy	5.90

The index of refraction n_{Na} was determined by Dr. Richmond as 2.023 ±0.003, a somewhat higher figure than has been previously reported. Both density and refractive index probably reflect the low water content of this microlite. The new determinations of density for microlite from other localities given in Table 1 confirm the usual lower densities previously found; the lower values will probably be found, when analyses are available, to be due to a general higher water content.

X-ray study. The *x*-ray powder picture is very sharply defined. The edge of the unit cell, calculated from this photograph by Prof. Shaub, is 10.39±0.01Å. This figure agrees closely with previous determinations made by Reuning (1933) and Bjørlykke (1934) on microlite of lower density. Hence the density variations would seem to be closely dependent on compositional variations and not on variation in cell dimension.

The cell contains 8 molecules of $X_2Z_2O_6(O, OH)$ with a total molecular weight of 4259, according to the analytical results which follow, and a calculated specific gravity of 6.27.

Chemistry. The chemical analysis was made by the junior author on several grams of selected clear green fragments without visible impurity. He followed the method of Hillebrand and Lundell. The results of the analysis, as shown in the following table, indicate a tantalum-rich sample of microlite with an unusually low water content. The discussion is by Dr. Berman and leads to a formula in agreement with Machatschki's (1932) earlier work on minerals of the same type.

Table 2. Analysis of Microlite, Topsham, Me.

	1.	2.	3.		4.
Ta_2O_5	74.27	.336	14.63	16.33	74.67
Cb_2O_5	3.56	.027	1.18		3.50
WO_3	0.17	.001	.04		
SnO_2	1.61	.011	.48		1.70
CaO	15.03	.268	11.68	17.26	14.33
MgO	0.07	.002	.09		
UO_3	0.77	.003	.13		0.54
Y_2O_3	0.35	.003	.13		0.78
Ce_2O_3	0.26	.002	.09		
Na_2O	3.37	.109	4.75		3.49
K_2O	0.41	.009	.39		
H_2O	0.27	.030	1.31		1.00
Total	100.14	1.289	0=56.08		100.00
G	6.41				6.265
Molecular Weight					4259.38

1. Analysis by F. A. Gonyer.
2. Atomic ratios.

3. Atoms per unit cell with Vd/A=4358 (from the x-ray data).
4. Calculated composition for $X_2Z_2O_6(O,OH)$ with
   $X=Ca_{1.36}Na_{0.60}(Y,Ce)_{.03}U_{.01}$
   $Z=Ta_{1.00}Cb_{0.14}Sn_{0.06}$ and $(O:OH)=0.41:0.59$

In column 3 of this table the agreement with the theoretical formula $8[X_2Z_2O_6(O,OH)]$ is shown. The X and Z atoms are somewhat in excess and the number of oxygen atoms is in excellent agreement. Column 4 is the calculated composition, with the atoms found in the analysis adjusted to conform with the formula. The simple *Ca,Na* microlite must contain equal atomic proportions of *Na* and (*OH*) in order to conform with the valence requirements. In this instance, however, the valence adjustments are somewhat more complex because *Sn*, a quadrivalent atom, substitutes for some of the quinquevalent *Ta* in the *Z* part of the formula; in the *X* part not only does *Na* substitute for *Ca* but also the rare earths which are trivalent, and a small amount of *U*, which is hexavalent. All of these substitutions lead to a net requirement of 0.59 (*OH*) in the formula, or 1.00 per cent of H_2O in the analysis. The most serious discrepancy is in the water, but by the method of calculation the errors in other parts of the analysis are thrown into this figure.

Brown microlite. In masses of the albite which lined the topaz pocket at Topsham there were observed occasional brown spots, at the center of each of which could be seen a tiny blackish crystal. Examination in the laboratory shows that these crystals are octahedrons, more or less distorted by intergrowth with the platy albite. The fracture is conchoidal and shows a resinous lustre. The powder under the microscope is quite transparent and of a rather brownish-yellow color. Similar crystals were later found in one or two specimens of lepidolite; these were perfectly symmetrical octahedrons with narrow to broad truncations by the dodecahedron. The maximum diameter was ¼ inch. The density of these dark crystals was determined by Mr. Draisin on three different samples. As shown in Table 1, the specific gravity is 6.36, nearly as high as that of the green microlite. Closely associated with the dark microlite are a few small crystals of columbite.

Stibiotantalite. In the list of paragenetic relations, mention is made of stibiotantalite. The specimen referred to is one of the two that were found at Topsham, each very small. Notwithstanding this relatively unimportant occurrence, it seems worthwhile to add some note upon it, since stibiotantalite has hitherto been found in America only at Mesa Grande, California.

The specimen, about half a square centimeter in area, consists of a crystal of microlite, one surface of which is coated with albite, a little sericite and about 30 tiny crystals of stibiotantalite. The pale gray to brownish crystals are about 1 mm. long and .3 mm. in greater diameter. Most of them are implanted by one end of the *c*-axis and show a single prism and a pyramid which are the forms *g*(130) and *w*(4.12.9) of Penfield and Ford (1906). The pinacoidal cleavage is perfect and truncates the thin edge of the prism.

Penfield and Ford (1906), who were the first to describe crystals of stibiotantalite, were convinced that this mineral was isomorphous with columbite; they therefore assigned to the principal forms complex indices whereby the elements were brought into a rather remote correspondence with those of columbite. They showed that stibiotantalite was hemimorphic with respect to the direction of the *a*-axis, that is normal to the perfect cleavage.

Ungemach (1909) was the next author to describe crystals of this mineral. He denied the relationship to columbite on purely chemical grounds; took the principal forms as unit forms; and, in order to follow ordinary convention, placed the hemimorphic axis vertical, that is he made the cleavage basal.

The strongest zone of stibiotantalite with five prisms and two pinacoids is the zone [001] of Penfield and Ford, which in Ungemach's position becomes [010]. With present usage this zone should be retained as [001], but the principal prism and pyramid should be unit forms as suggested by Ungemach. Our choice of position therefore is a third alternative, with Penfield and Ford's axes *a* and *b* interchanged and their form (4.12.9) made (111).

The transformation formulae relating these three positions are the following:

Penfield-Ford to Ungemach	$0\frac{1}{12}0/00\frac{1}{9}/\frac{1}{4}00$
Penfield-Ford to Palache	$0\frac{1}{12}0/\frac{1}{4}00/00\frac{1}{9}$
Ungemach to Palache	100 /001/010

The elements of stibiotantalite as given by Ungemach are: $a:b:c = 0.8879:1:2.1296$. The work of Dihlström (1938) confirms this axial ratio. He found the unit cell to have the dimensions $a_0 = 4.916$Å, $b_0 = 5.542$Å, $c_0 = 11.78$Å; or $a_0:b_0:c_0 = 0.888:1:2.126$. There are four molecules of $SbTaO_4$ in the unit cell, and in our position the space group symbol is *Pcn*.

Recalculated to Palache's position, the elements become

$$a:b:c = 0.4169:1:0.4696.$$

The Topsham crystals show no evidence of hemimorphism or twinning. The faces are dull and give poor reflections but could be identified as the unit forms. Figure 2 illustrates their form. In this position perfect

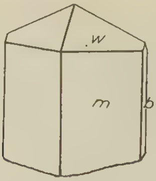

FIG. 2. Crystal of stibiotantalite.

cleavage is parallel to (010) and the *b* axis is the axis of hemimorphism. The following angle table has been calculated from Penfield's measurements with slight emendation of his elements. The form list follows Ungemach (1909) with correction of two mistakes of transformation made by him and recurring in *Goldschmidt's Atlas*, **8,** 85.

Since no angle table has been published for stibiotantalite, one is presented here, based on the measurements of Penfield and Ford.

TABLE 3. ANGLE TABLE OF STIBIOTANTALITE—$SbTaO_4$

Orthorhombic; hemimorphic—*m2m*-

$a:b:c=0.4169:1:0.4696$; $p_0:q_0:r_0=1.1264:0.4696:1$

$q_1:r_1:p_1=0.4169:0.8878:1$; $r_2:p_2:q_2=2.1295:2.3986:1$

Forms		ϕ	$\rho=C$	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
c	001	—	0°00′	90°00′	90°00′	90°00′	90°00′
b	010	0°00′	90 00	90 00	90 00	—	0 00
α	190	14 55½	90 00	90 00	75 04½	0 00	14 55½
β	170	18 55	90 00	90 00	71 05	0 00	18 55
γ	150	25 37½	90 00	90 00	64 22½	0 00	25 37½
n	130	38 38½	90 00	90 00	51 21½	0 00	38 38½
m	110	67 22	90 00	90 00	22 38	0 00	67 22
η	012	0 00	13 13	13 13	90 00	90 00	76 47
e	011	0 00	25 09½	25 09½	90 00	90 00	64 50½
h	032	0 00	35 09½	35 09½	90 00	90 00	54 50½
l	021	0 00	69 55	69 55	90 00	90 00	20 05
δ	101	90 00	48 24	0 00	41 36	41 36	90 00
w	111	67 22	50 40	25 09½	44 26½	41 36	72 41
x	133	38 38½	31 01	25 09½	71 14½	69 25	66 16
y	132	38 38½	42 03	35 09½	65 16½	60 36½	58 27½
ε	171	18 55	73 56½	73 05	71 51	41 36	24 37

The identity of the Topsham stibiotantalite was further established by optical and density determinations. The specific gravity was determined with the microbalance on 3.5 mg. of fragments as 6.57. This figure is intermediate to the two determinations made by Penfield and Ford on two samples, 6.299 to 6.818. The optical properties were compared by Dr. Berman with those of material from Mesa Grande and were found to be qualitatively the same. Exact measurements were not made, however.

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HYDROUS IRON SULPHIDE IN CALIFORNIA CRYSTALLINE LIMESTONE*

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Hydrous iron sulphide, called hydrotroilite, has been reported by Russian and perhaps by other workers as a constituent of unconsolidated or poorly consolidated continental and marine sediments, from Russian and other localities (1). A similar black, easily soluble, hydrous iron sulphide occurs in the crystalline limestone at two southern California localities.

On the northwest slope of Ontario Peak, in the eastern San Gabriel mountains, there is a steeply dipping series of crystalline limestones and quartzites, intruded by plutonic rocks. In addition to carbonates, a varied assemblage of metamorphic minerals has developed chiefly in the limestone. Within a distance of three quarters of a mile, garnet, malacolite, corundum, tremolite, forsterite, soda amphiboles, lazurite, fuchsite, and other minerals occur in some abundance (2). Near the mouth of Cascade Canyon, in the SW $\frac{1}{4}$ of sec. 31, T2N, R7W, San Bernardino Base and Meridian, the limestone is colored a very dark bluish gray, or nearly black, by the iron sulphide. Boulders of the same material as well as a black, partly serpentinized, impure dolomite are to be found scattered down stream. The surfaces of the boulders are nearly always very light colored, or only slightly iron stained and commonly much corroded. The black color of the unweathered rock is only to be seen on breaking through the white outer layers.

At a second locality, 30 miles southeast, in the "New City Quarry" near Victoria Avenue, Riverside, a bed of similar crystalline limestone with garnet and forsterite, perhaps 50 feet thick and a few hundred feet long, stands nearly vertical in quartz diorite. The white limestone contains thin dark bands and patches, some of which are composed of graphite flakes, others of yellow-bronze pyrrhotite grains, coated by black material, and still others entirely of a finely granular black iron sulphide.

At neither locality does the limestone have a fetid odor. The forsterite found at these localities appears to be the first recognized in California, as this mineral is not listed by Pabst (3).

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Cascade Canyon Occurrence

The fresh rock has a deep bluish black color, corresponding to the quaker blue shown at 5-E, Plate 40, of Maerz and Paul's dictionary of color (4). A lens shows the presence of scattered, minute, brassy grains of pyrite (harder than steel, insoluble in HCl). The rock is soft and easily scratched by the knife; its powder is non-magnetic.

The material studied in thin sections is a calcite-forsterite rock in which the forsterite has mostly altered to serpentine. The serpentine is intricately penetrated by the opaque sulphides, some secondary calcite, and a brown translucent mineral which is probably an iron oxide. Minor original minerals are pale garnet, colorless mica, and rutile.

Upon treatment with dilute hydrochloric acid the black pigmenting material as well as the calcite and some of the other constituents of the rock pass readily into solution with evolution of hydrogen sulphide. The remaining residue is almost entirely white, and usually shows no undissolved black minerals under the lens. Hot dilute sulphuric acid also completely dissolves the black material with evolution of hydrogen sulphide.

The attack is somewhat slower with cold dilute sulphuric acid due to the protective action of precipitated calcium sulphate, but after the lapse of half an hour the black mineral is completely dissolved. Even dilute acetic, oxalic or citric acids dissolve the black material with the evolution of hydrogen sulphide.

When ignited in a closed tube, fumes of hydrogen sulphide are evolved along with a small amount of water which shows a slight but definite acid reaction to litmus. No sublimate of sulphur was observed. The strongly ignited material shows a white or faintly pinkish color on cooling.

Chemical analysis. A spectrographic analysis of the material by Dr. T. G. Kennard showed the following constituents to be present in the proportions indicated.

Large	Mg
Medium	Al, Fe
Small	Si, Ca
Very small	Na, K, Ti
Traces	Li, Ba, B, Cu, Mn
Extreme traces	Ga, V

Quantitative analysis, after treatment with hot dilute hydrochloric acid, gave the following results:

H_2O	11.90%	
SiO_2	13.65	
Al_2O_3	3.40	
Fe_2O_3	2.26	
CaO	8.27	
MgO	9.14	
S	1.57	(aqua regia solution)
CO_2	5.97	
Insoluble	44.98	
	101.14%	
Less 0, equivalent to S and S_2	.73	
	100.41%	

Since it was highly probable that some of the iron and sulphur shown in the above analysis was derived from other sources than the iron sulphide dissolved by the weak acids, a second determination for the iron and sulphur obtained from a hot, four per cent solution of oxalic acid was made with the following results:

Fe_2O_3	(dissolved in 4% oxalic)	2.20% of rock
S	(dissolved in 4% oxalic)	0.37% of rock

From the iron and sulphur percentages in the oxalic acid extract, and the sulphur extracted by aqua regia, it was calculated that the rock contains about 2% FeS_2, pyrite, and 1% FeS, probably as hydrotroilite.

RIVERSIDE OCCURRENCE

The sulphide-bearing rock at the Riverside "New City Quarry" near Victoria Avenue is a coarsely crystalline white limestone, containing calcite crystals more than 1 cm. across. Dark streaks and patches are in most cases pyrrhotite and probably hydrotroilite, more rarely graphite in flakes up to 2 mm. diameter. The sulphide grains commonly have cores of bronze-yellow pyrrhotite, which is magnetic and fairly easily scratched by a needle; other grains are entirely black and very soft. Part of the black material appears to be magnetic; it may be melnikovite, the magnetic form of FeS_2 (1). A few $\frac{1}{4}$ mm., wholly unaltered, hexagonal, short pyramidal crystals of pyrrhotite are present. The best crystal was exceptional, in that it was not visibly attracted by a $1\frac{1}{2}$ inch alnico horseshoe magnet. On this crystal Mr. Edgar Bailey identified the forms *c*, *m*, *s*, *z*, with *i*$(10\bar{1}2)$ listed as doubtful.

Thin sections prepared from the darkest portions of the rock, showed that the black sulphide occurred as stringers of exceedingly fine particles filling cracks and surrounding individual grains of calcite, serpentine, and other minerals. When treated with citric or stronger acids, the rapid solution of the black mineral was observed. In most cases a skeleton of undissolved white material remained which maintained the shape of the section. Microchemical tests carried out on the section at the time of solution showed the presence of much hydrogen sulphide. When oxalic acid was used, only parts of the black areas were attacked with the formation of yellow ferrous oxalate and the liberation of hydrogen sulphide.

Petrographically the rock is similar to that from Cascade Canyon, a calcite-forsterite rock with pale and deep-red garnet, idocrase, uniaxial white mica, and opaque sulphides. Some of the forsterite is clear and colorless, with rounded outlines which reveal only suggestions of crystal faces. It shows little or no cleavage, optically probably positive, with $\alpha = 1.635$, and $\gamma = 1.671$, both $\pm .003$. The serpentine often enmeshes residual forsterite areas (Fig. 1). The indices of at least part of the serpentine are approximately $\alpha = 1.545$ and $\gamma = 1.550$. The mica is optically identical with a coarser grained pale green mica from North Hill, Riverside, which is an Mg-Al silicate with Cr, Fe, Na, and K; it appears uniaxial or has a barely perceptible (2°–3°) 2V; γ is somewhat variable, 1.580–1.584 $\pm$ .002; $\gamma - \alpha = .035$–.040; apparently the mineral is a chrome eastonite (5). The principal garnet is nearly colorless, pinkish or pale lilac-gray; crystals are minute malformed octahedrons modified by the

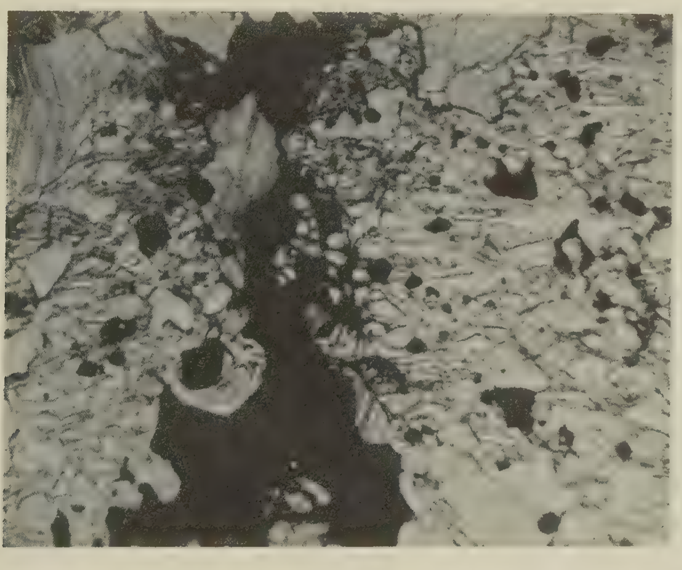

FIG. 1. Sulphides in crystalline limestone, New City Quarry, Riverside, Calif. Striated areas: calcite; meshed areas: forsterite veined by serpentine; black: sulphides and a few rutile grains. The veinlike black material is mostly pyrrhotite, the thin black veinlets mostly hydrotroilite. ×22. Photomicrograph by David Howell.

rhombic dodecahedron; *n* is approximately 1.72, and hence the mineral is grossularite, or possibly pyrope. A very few even smaller, deep red, iron garnets appear to be rhombic dodecahedrons. Deep brown, nearly opaque grains with high relief and very low double refraction are considered to be an iron oxide. A substance occurring as numerous minute black, submetallic crystals and found by spectrographic analysis to be a Mg-Ti compound with some Mn, is not a manganiferous geikielite, for thin slivers are deep brown in color and isotropic. It may be a new mineral. A single octahedron, one millimeter in size, of magnetite or magnesioferrite was also found. A few very dark sky-blue grains, with no apparent cleavage, slight pleochroism, low double refraction and high indices may be serendibite (6). The opaque sulphides cut the other constituents, as shown in Fig. 1.

Brucite, nontronite, pyroxenes and wollastonite are abundant in the City Quarry, but were not found in association with the sulphide bands. Many other minerals have also been found in this limestone mass.

Chemical analysis. In the analysis of the Riverside rock recourse was made to the use of citric acid as the solvent. Attempts to make separations of the black sulphide by means of heavy liquids proved unsuccessful due to the fact that it existed in such fine division and in such close association with calcite and serpentine that all three were floated in the liquids. Therefore, an average sample of the whole sulphide-bearing rock was taken for the analysis.

Quantitative determinations were made with the results which follow, one gram samples being used for the analyses. Four per cent citric acid was used as the solvent.

Insolubles	36.34%
Soluble (by difference)	63.66

Total water in original rock	4.68%
Water recovered from oven-dried insolubles	1.88
Difference, or water assigned to soluble portions	2.80

Summary of constituents found in portion soluble in citric acid:

H_2O (see above)	2.80%
SiO_2	1.57
Al_2O_3	0.74
FeO	1.37
CaO	28.12
MgO	6.71
S* (evolved as H_2S with citric acid)	0.14
CO_2	21.20
	62.65%
Less O, equivalent to S	.11
	62.54%

*Equivalent to 0.38% FeS.

Alkalies were not determined.

Examination of the insoluble fraction showed the presence of colorless mica, precipitated finely granular silica, quartz, unattacked pyrrhotite, and a few crystals of garnet.

A study was made of the effect of citric acid on serpentines which showed that the iron sulphide must be freed from serpentine before its water content could be estimated. This was accomplished by repeated centrifuging with methylene iodide. Microscopic examination of the heavy separate showed it to consist of garnet and pyrrhotite as well as the amorphous black mineral, but to be free from limonite and serpentine.

When the heavy separate is treated with 4% citric acid, H_2S is evolved and some iron passes into solution. The reaction takes place either upon heating or in the cold.

When five hundred milligrams of the heavy separate had been collected, washed with benzene, and dried at 110° for 4 hours, a Penfield determination for water was made using previously fused PbO as a retainer for S. Under these conditions 1.28% of H_2O was recovered from the separate, indicating about 3% H_2O (above 110°) for the black sulphide.

Control experiments using pyrite, pyrrhotite, and marcasite gave negative results for H_2O.

Discussion

Microscopic examination and qualitative reactions indicate that a black metallic sulphide is present as the pigmenting material of the limestones. Spectrographic and chemical analyses show that, aside from iron, no element capable of forming dark colored sulphides is present in sufficient abundance to account for the color of the rock. Microscopic and microchemical study showed two sulphides to be present in each case. Only one of these was soluble when boiled with dilute oxalic or citric acid.

For the Cascade Canyon material, amounts of iron and sulphur in the entire rock and in the fraction soluble in oxalic acid can only be satisfied by two iron sulphide minerals. The monosulphide, dissolved in dilute oxalic acid, makes up about one per cent of the total rock, and pyrite, which is not dissolved in the oxalic acid, is present to about two per cent.

In the case of the Victoria Avenue material, the sulphur recovered from the treatment of a typical sample of the black rock with citric acid is small, 0.14 per cent. When calculated as the monosulphide only 0.38 per cent is shown. Analysis of a concentrate showed that the black sulphide must be hydrous. The black iron sulphide is probably $FeS.nH_2O$. It might be a polysulphide from our quantitative data, but qualitative data suggest hydrotroilite in every respect but one. The California mineral does not oxidize as readily as the hydrotroilite described by Doss (1).

It should be noted that Tarr (7) found a non-magnetic black iron sulphide, which he compared to melnikovite, with pyrite and marcasite in Missouri limestones. His published description does not exclude the possibility that he was dealing with hydrotroilite. Ehrenberg (8) has described a dark yellow gel-formed pyrite with a composition between FeS and FeS_2.

Origin of the Hydrous Iron Sulphide

Hydrotroilite and serpentine are among the youngest minerals present at either locality. They may both belong to a very late hydrothermal stage, later than most of the minerals listed as "late hydrothermal" by Richmond (6), or the hydrotroilite may represent a first stage in the weathering of the other iron sulphides. We think that the hydrotroilite is probably hydrothermal, though convincing evidence is lacking.

Acknowledgments

We are grateful to Dr. T. G. Kennard of Claremont Colleges for numerous spectrographic analyses, to our colleague, Mr. Edgar Bailey, for goniometric measurements and helpful suggestions, and to Professor emeritus J. E. Wolff of Harvard, now residing in Pasadena, for the use of a large Fuess one-circle goniometer.

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8. Ehrenberg, H., Das Auftreten und die Eigenschaften ehemaliger FeS_2-Gele insbesondere auf metasomatischen Blei-Zinkerzlagerstätten: *Neues Jahrb. Mineral. u.s.w., Beil.* **57A,** 1303–1320 (1928).

CRYPTOCRYSTALLINE PYRITE FROM ALPINE COUNTY, CALIFORNIA

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Introduction

A few months ago the writer enjoyed the opportunity of visiting the Leviathan mine with a party from the California State Division of Mines. This mine is located on the eastern, right, bank of Leviathan Creek at an elevation of about 7,200 feet, seven miles east of Markleeville, the county seat of Alpine County (Fig. 1). The mine is owned by the Leviathan Sulphur Co., and is leased at present by the Calpine Corporation, a subsidiary of the Texas Gulf Sulphur Co.

Shipments of sulphur have been reported[1] from Alpine County only during 1933 and 1934, but the amount produced has not been made public. Though the reserves of the Leviathan mine are large, production so far may not have been more than a few hundred tons.

At the entrances to the mine there is no sulphur in evidence, but seams of sulphur are said to reach the surface at higher levels. The deposit was discovered through workings of a small copper mine located just above it, and long since abandoned.

The Sulphur Deposit

The main body of the sulphur occurs as an impregnation of a completely opalized, fine grained, andesite tuff. The sulphur content of this material is 35% or more, but the mixture of sulphur with other materials is such that economical separation has proved most difficult. The opalized tuff is a nearly horizontal sheet about 100 feet thick between other volcanic rocks, mostly andesitic mud-flows and breccias. No detailed geologic map of the region has been published, but the new Geologic Map of California (1938) shows only tertiary volcanic rocks for miles in all directions (Fig. 1).

Access to the deposit is gained by tunnels run in at the top and bottom of the sulphur-impregnated tuff and by numerous crosscuts and raises. Both tunnels enter the deposit through the so-called footwall, a fault that dips east under the ore and makes its western boundary. The lateral walls of the deposit are also determined by faults, but these have been touched by the mine workings in only a few spots.

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[1] *Bulletins* **110** and **111**, *California State Division of Mines.*

The sulphur appears to have been introduced through fault fissures and trapped in the opalized tuff. The western part of the deposit, adjoining the footwall fault, is greatly fractured and traversed by veins of almost pure sulphur, some of them several yards thick. This is the high grade ore. Smaller amounts of high grade ore occur at various points in the mine. Breccias of opalized and sulphur-impregnated tuff fragments in pure sulphur are also common in the western part of the deposit.

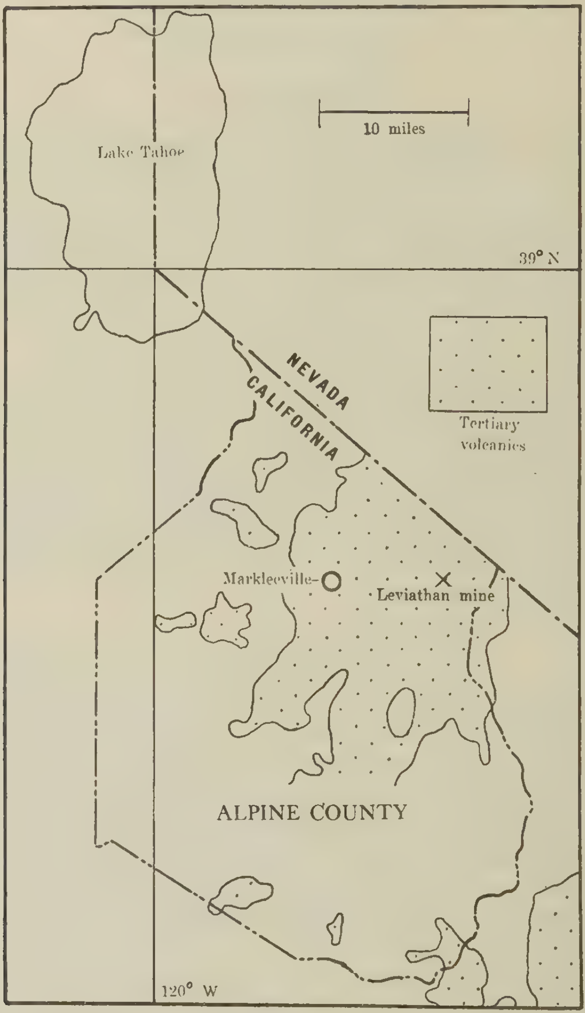

FIG. 1. Distribution of tertiary volcanic rocks in Alpine County, from Geologic Map of California, 1938.

The main body of sulphur-impregnated tuff is pale grayish yellow in hand specimen, still showing faintly the original banding. Joints or cracks are lined by a thin coating of sulphur in which small crystals are recognizable. The density of this mixed material is 1.98–2.03, but since this is very close to the density of either sulphur or opal one can draw no conclusions from this figure as to the proportions of the constituents. In thin section the sulphur appears mostly in irregular, rather coarse-grained, patches in the interstices of almost wholly opalized tuff. No replacement of structures by the sulphur was observed.

The mine waters are highly acid and secondary sulphates are found in many parts of the mine. So far chalcanthite, iron-copper chalcanthite, römerite, melanterite and halotrichite have been identified.[2] The blue and red brown coatings of chalcanthite and römerite on masses of solid sulphur make as colorful a mine wall as anyone could wish.

Cryptocrystalline Pyrite

Some peculiar varieties of pyrite occur with the sulphur. They are found for the most part on the fringes of the deposit, especially at the lower level. The pyrite is all cryptocrystalline and mostly black or gray, only the most compact specimens showing a brownish color. The luster is earthy or dull, in a few cases submetallic. Some of the material is quite friable, but in part it reaches the normal hardness of pyrite. In a few places this pyrite occurs with sulphur, in one specimen forming selvages of hard pyrite around clean coarse fragments of sulphur embedded in friable black pyrite.

Since the nature of this peculiar pyrite was at first in doubt it was examined in detail. Microscopic examination of thin sections and polished surfaces showed that the very fine grained pyrite has replaced the opalized tuff (Figs. 2 and 3). Some phenocrysts have been perfectly pseudomorphed by the replacing pyrite. Such material was collected at several points in the mine at the base of the sulphur deposit. Close examination of this replaced material also shows a few minute veinlets of cryptocrystalline pyrite.

Satisfactory polished surfaces can be obtained only from the more compact specimens which develop the typical pyrite luster and color on polishing. The softer, friable, pieces show only specks here and there that assume the common appearance of pyrite. No trace of any other metallic mineral was found in the polished surfaces. Thin sections showed only voids and chalcedony or opal in addition to pyrite. It seems probable that the tuff suffered a double replacement in some parts, being first

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[2] Gary, Geo. L., Sulphate minerals at the Leviathan sulphur mine, Alpine County, California: *Calif. Jour. Mines and Geology*, **35**, no. 4 (Oct. 1939).

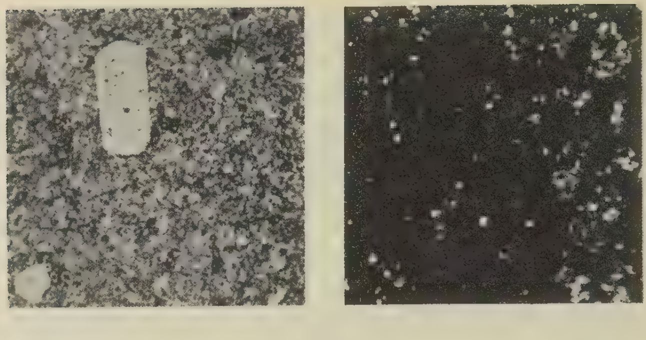

Fig. 2 (left). Phenocryst and groundmass replaced by pyrite in reflected light. Magnification 12.5×.
Fig. 3 (right). The same as Fig. 2 by transmitted light. Same magnification.

opalized and then almost completely pyritized. In places where the pyrite is soft and friable, or mixed with sulphur, replacement is not readily apparent.

Well within the main body of sulphur ore there occurs a mass of rather pure glistening yellow sulphur. Associated with this is a considerable amount of sulphur that has the typical fracture and luster, but is dark brown or black. Microscopic examination shows that this peculiar color is due to finely disseminated pyrite in rather coarse grained massive sulphur. In part the pyrite shows faint banding and is gathered into clusters (Fig. 4). The maximum density determined on this material was 2.35, as against 2.04 for the adjoining pure sulphur. From these figures and the known density of pyrite it can be calculated that the dark sulphur contains nearly 10 per cent pyrite by volume or over 20 per cent by weight, in agreement with estimates from the microscopic observations, though the pyrite cannot be seen at all in the hand specimen.

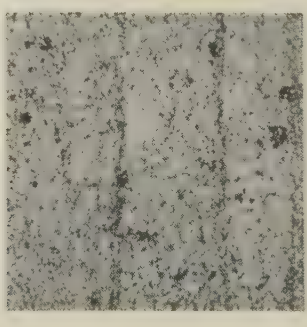

Fig. 4. Thin section of pyrite in coarse sulphur, Transmitted, ordinary, light. Magnification 4.2×.

Two portions of the cryptocrystalline pyrite were selected for further study:

A—The hardest and most compact, and
B—The soft, black, friable, pyrite.

X-ray powder patterns of the two varieties were kindly prepared by Mr. W. H. Dore of the Division of Plant Nutrition, College of Agriculture, University of California. The patterns show only the lines of pyrite and are identical except that the one from the soft material is a little stronger. The lattice constant, calculated from 21 measured and indexed lines is 5.396±0.010Å for both varieties. This differs less than 1/500 from the accepted value, 5.405Å, (*SB*. I).

The density of the friable material is not readily obtainable because the powder behaves badly in a pycnometer. The same is true of the more compact material when powdered. The highest value of the density obtained by using a Jolly balance on selected fragments of the compact variety, without visible inclusions or holes, was 4.3. This is far below the theoretical value, 4.97, for pyrite. From the microscopic examination and the analysis it is certain that this discrepancy is due to impurities and voids in the specimen.

Spectrographic examination by Dr. T. G. Kennard of Claremont, California, yielded the following results:

	A	B
	Dark compact pyrite	Black friable pyrite
Large amount	Fe	Fe
Medium to small	—	Ni, Ti
Small, X%	Ti	Si
Very small, 0.X%	As, Ni, Si	As, Cr
Traces, 0.0X% or 0.00X%	Na, Ca, Mg, Al, Cr, Cu, Mn, V	Na, Ca, Mg, Al, Cu, Mn, V

suggesting that the most important chemical difference may be a slightly higher concentration of nickel, titanium and chromium in the friable variety.

Somewhat incomplete quantitative analyses of both varieties were made by Mr. W. H. Herdsman of Glasgow, and are recorded below.

	A	B
	Dark compact pyrite	Black friable pyrite
Fe	40.26%	34.40%
S (total)	48.80	41.24
SO_3	2.60	7.37
H_2O	2.56	5.33
Insoluble residue	5.22	7.25
Total	99.44	95.59
Correction for S	−1.07	−3.03
Corrected total	98.37	92.56

In addition the analysis of the black friable pyrite showed several tenths per cent of nickel. The correction to the totals of the analyses is for S reckoned both in the total S and in the SO_3. The ratio of S not in SO_3 to Fe is 2.021 for Sample A and 1.935 for Sample B, which must be considered satisfactory for analyses of this character. The SO_3 shown in the analyses is partly from free sulphuric acid. Most specimens of the cryptocrystalline pyrite develop crusts of melanterite or other secondary minerals even though they may at first appear quite clean. Some have grown several "crops" within a few months.

Comparison with Related Materials

Black, cryptocrystalline or amorphous FeS_2 has been described by Doss[3] occurring as small granules in miocene clay encountered in a bore hole in Russia. His accounts are extremely diffuse, but, at least it is certain that he wished to apply the name melnikovite to what he considered to be a new mineral of the composition FeS_2, which is black, magnetic, has a hardness of 2 or 3, and a density of 4.2–4.3. He expressly stated that he considered this material to be distinct from marcasite or pyrite and that it is an "iron bisulphide gel become crystalloid." He also described the alteration of melnikovite to pyrite.

The name melnikovite has not been widely adopted and, indeed, material of this character is not common. Niggli[4] has used the term in his textbook in two senses. In one place he uses it to designate "$FeS_2 . nH_2O$" of colloidal character from which dense marcasite has formed. In another place he lists it as a "metacolloid" equivalent to pyrite or pyrrhotite, with the name "Melnikowitgel" for a "Gelmineral" of the composition "$FeS \cdot nH_2O$, possibly bisulfide or oxysulfide."

Tarr[5] used the name melnikovite for "amorphous black iron disulphide." He applied it "tentatively" to a "soft black powder" occurring with marcasite and pyrite. The only reason for his uncertainty in applying the name melnikovite appears to have been that the black powder was not magnetic, as was the material for which the name was first used.

Ehrenberg[6] has described cryptocrystalline iron sulphides, having an

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[3] Doss, B., Über die Natur und Zusammensetzung des in miocänen Tonen des Gouvernements Samara auftretenden Schwefeleisens; *Neues Jahrb. Min.*, etc., *BB.* **33,** 662–713 (1912); and Melnikowit, ein neues Eisenbisulfid, und seine Bedeutung für die Genesis der Kieslagerstätten: *Zeits. prakt. Geol.*, **20,** 453–483 (1912).

[4] Niggli, P. *Lehrbuch der Mineralogie*, 2nd. Ed., **2,** pp. 490, 678 (1926).

[5] Tarr, W. A., Alternating deposition of pyrite, marcasite and possibly melnikovite: *Am. Mineral.*, **12,** 417–421 (1927).

[6] Ehrenberg, H., Das Auftreten und die Eigenschaften ehemaliger FeS_2-Gele insbesondere auf metasomatischen Blei-Zinkerzlägerstatten: *Neues Jahrb. Min.*, etc., *BB.* **57,** 2 (1928).

S/Fe ratio slightly less than 2, which yield x-ray patterns showing only pyrite lines. The sulphur deficiency he ascribes to the presence of pyrrhotite which can be made visible by annealing. The original manner of distribution of the pyrrhotite is left in doubt. The very fine grained parts of this material are designated by Ehrenberg as "the gel form of the compound FeS_2, which Doss called melnikovite."

Schneiderhöhn and Ramdohr discuss " 'Melnikovit-Pyrit' Kristallin gewordenes FeS_2-Gel" as mineral number 37 in their textbook on the microscopy of ores.[7] Following Ehrenberg, they consider that the finely banded and colloform habit of the material indicates that it formed from a gel, a view of the origin of colloform pyrite also held by Smitheringale.[8] The material referred to by Ramdohr and Schneiderhöhn and the authors they cite differ from the melnikovite of Doss in various respects, particularly in being harder and not black.

Conclusions

1. The name melnikovite and various derivatives have been applied to cryptocrystalline forms of pyrite by several writers. It is not certain that any of them dealt with material closely resembling the original melnikovite.
2. A gel condition or origin has been ascribed to material called melnikovite by the originator, and by later users of the name. Not one of these writers has shown that solid FeS_2 occurs in a non-crystalline state. In the only two cases, known to the writer, in which the x-ray diffraction method has been used, the German occurrences described by Ehrenberg and the material from Alpine County described here, the material in question has been shown to be pyrite.

Acknowledgment

The work here reported was made possible in part through aid of a grant from the Board of Research of the University of California. The writer is very grateful for this assistance.

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[7] Schneiderhöhn, H., and Ramdohr, P., *Lehrbuch der Erzmicroskopie,* **2,** 170–173 (1931).

[8] Smitheringale, W. V., Mineral association at the George gold-copper mine, Stewart, B. C.: *Econ. Geol.,* **23,** 193–208 (1928).

NOTES AND NEWS

MINERAL NOTES FROM THE MICHIGAN IRON COUNTRY

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It is the purpose of this paper to place on record the occurrence of several minerals heretofore unreported from the iron districts of Michigan. They are *stilpnomelane*, *halloysite*, *nontronite*, and *dihydrite*.

The first mineral, *stilpnomelane*, comes from the ferruginous Upper Huronian slates of Crystal Falls, where it is exposed along the east bank of the Paint River, four to five hundred feet below the power dam. It was formed by hydrothermal reaction accompanying the emplacement of quartz-adularia pegmatite veins. It borders these veins in plates or books up to twelve centimeters across, and branches out into the slate as veinlets with scattered adularia inclusions. To a slight extent, also, it replaces the slate as a fine-grained schist, and it enters the quartz and adularia as apophyses which occasionally develop a crude comb structure similar to that illustrated by Grout and Thiel[1] from the Minnesota iron formations. Unlike their material, the Crystal Falls stilpnomelane contains no potash, is exceptionally high in ferric iron and low in ferrous, and, in addition, contains appreciable manganese, as shown in the following analysis by my colleague, Professor Bartholow Park, and myself:

Stilpnomelane, Crystal Falls, Michigan

SiO_2	42.42
Al_2O_3	6.71
Fe_2O_3	33.24
FeO	0.85
MnO	2.27
MgO	5.20
H_2O+	8.33
H_2O-	1.45
Total	100.47

To prove the absence of potash Professor Park used the arc spectrograph. Other elements whose lines do not show in the photographs include calcium, chromium, and titanium. Present in traces are sodium, lithium, cobalt, nickel, vanadium, barium, and zinc. All material used in our analysis was carefully selected under the microscope to insure freedom from contamination, especially by quartz, feldspar, pyrite, or manganese stain. As is to be expected from the amount of ferrous iron, less than one per cent, the color is not the usual green, but is chestnut brown, and the streak is distinctly brownish. The luster is resinous and splendent, to earthy. The mineral is very slowly decomposed by hydrochloric acid, is not at all attacked by sulphuric, but is rapidly soluble in warm hydrofluoric—factors which called for the "borax snow" method in the determination of the ferrous iron. The optical data are not at all unusual; the refractive indices are: β and $\gamma = 1.730 \pm 1$, and $\alpha = 1.634 \pm 2$. The optic angle does not differ perceptibly from 0°. Y and Z are golden yellow to chestnut brown, depending upon the thickness, and X shows much less absorption. Fractures normal to the micaceous cleavage are common and, whether or not fortuitous, the extinction angles in such slices are predominantly 4° or 13°.

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[1] *Am. Mineral.*, **9**, 228–231 (1924).

Halloysite, the next mineral to be described, was encountered in the New Richmond iron pit, two and one quarter miles east of Palmer, Michigan, on the Cascade Range. There it is most abundant as a cavity lining in coarse specularite-tourmaline-quartz veins, but it also occurs along with nontronite as a filling of narrow cracks in the ore. Its deposition is more readily accounted for by supergene agencies than by hydrothermal. The halloysite was identified by its isotropic character (although flecked with spots showing faint double refraction), by its refractive index of 1.555 ± 2, and by its x-ray diffraction pattern. Another colleague, Professor Roy Drier, supervised the x-ray analysis. Several extra lines show up faintly in the film; they are due neither to kaolinite nor to alunite, the two most common impurities. The alumina in the halloysite, nearly forty per cent, must have been introduced from outside, since the rock from this mine, a siliceous hematitic ore, carries but 1.17 per cent.[2]

Nontronite, $(Ca, Mg)O.\ 2Fe_2O_3.8\ SiO_2.7 \pm H_2O$, another clay mineral from the same pit, is abundant as a gouge in a shatter zone, where its deposition followed that of botryoidal hematite and limonite, and goethite. Judged from this association, the nontronite is clearly supergene. It also lines thin seams in the ore along with slightly earlier or overlapping halloysite. Its properties follow. The nontronite, originally green or bluish-green like chrysocolla, turns black and magnetic before the blowpipe. It is very slowly soluble in hydrochloric acid, with gelatinization. With the hand lens it appears either dull and earthy or smooth and enamel-like, although occasional fibers are coarse enough to produce a silky luster. Most of these fibers measure but 0.0025 mm. in thickness. Under the microscope their elongation is determined as positive (with parallel extinction), and their refractive indices are 1.565 ± 2 for α and 1.586 ± 2 for γ. The arc spectrum as photographed by Professor Park shows the presence of magnesium to the amount of one per cent, but only the barest traces of calcium and aluminum. An *x*-ray diffraction pattern agrees closely with Gruner's published data[3] for the mineral. Since establishing its identity the writer has encountered films of nontronite in ores from the Menominee and Gogebic ranges as well. Apparently it is not at all an uncommon species in the Michigan iron districts.

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[2] Analysis Booklet for 1938 issued by the Lake Superior Iron Ore Association.

The fourth mineral, *dihydrite*, a hydrous copper phosphate, was found by a student, Charles Upson, while looking for nontronite, and was at first mistaken for that iron clay. The location is about four and one-half miles west of the New Richmond mine, and eight hundred feet south of the East pit of the Tilden mine. It occurs as thin crusts in a fault zone passing through sericitized granite sills in Middle Huronian slate, and is evidently hydrothermal. The usual emerald green color is diluted to a robin's-egg blue in the films, which average 0.01 mm. in thickness. Around the edges of this earthy aggregate high magnification resolves fibers and bladed crystals which, despite their near-colloidal size (seven microns in width and three in thickness), lend themselves remarkably well to identification by optical means. The crystals, being microlitic, are of simple habit, elongated parallel to the vertical axis and flattened parallel to the side pinacoid. The termination is nearly, but not quite, perpendicular to the *c* axis. A second habit, comparatively rare, shows a polysynthetic twinning which brings basal and side pinacoids together in a common plane. These give extinction angles of five and of twenty-one degrees, respectively. Thus our specimens, optically at least, are triclinic—in *Dana's System of Mineralogy* dihydrite is recorded as "monoclinic or triclinic." There the pleochroism formula is given as: $Z =$ deep bluish green; $Y =$ yellowish green; and $Z =$ bluish green. In our specimens the X and Y colors are reversed. Our refractive indices ($\alpha = 1.708 \pm .002$, $\beta = 1.753 \pm .002$, $\gamma = 1.800 \pm .005$) are slightly lower than those given in Larsen's tables.[4]

In conclusion, it may be stated that, in our attempts to identify the nontronite, an iron silicate, we first made blowpipe tests for copper, for phosphorus, and for other elements that might be the source of the green color. When dihydrite, the actual copper phosphate, came to hand, ironically enough no chemical tests were made until the optical data suggested its identity.

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[3] *Am. Mineral.*, **20**, 478 (1935).

[4] *U. S. Geol. Sur., Bull.* **848**, 197.

SOME CONSTITUENTS OF METEORITE RUSTS

JOHN DAVIS BUDDHUE, *Pasadena, California*

I have stated elsewhere that the mineral composition of meteorite rusts is still unknown but that the magnetism suggests magnetite.[1] The presence of magnetite is further indicated by the observation of Krantz of octahedral and dodecahedral crystals in druzy pits in the oxide of Xiquipilco (Toluca), Mexico. He regarded these as magnetite.[2] I have myself observed similar crystals on the oxide coating of an iron of uncertain origin, but which is very probably a member of the same fall. Meunier treated the rust of this meteorite (Toluca) with bichloride of mercury and hydrochloric acid and analyzed the residue. This contained (Fe,Ni)O and Fe_2O_3 in almost the exact proportions for magnetite.[3] It is thus almost certain that this meteorite rust contains magnetite, or perhaps a mixture of magnetite and trevorite, the only objection being that the specific gravity of 4.89 is somewhat low for magnetite which averages about 5.17. This, of course, does not prove that magnetite is always present in such oxides, but it does show that it can occur if FeO is present. Even if FeO is absent, trevorite could probably be formed from the NiO which is present.

I have to report a new analysis of the oxide of the Xiquipilco meteorite made by G. D. Van Arsdale, assayer in Pasadena, California. In a sample of about two grams he reported:

Fe_2O_3	74.98%
FeO	9.00
(Ni+Co)O	5.15
P	0.13
S	trace
Loss at 110°C.	0.48
Ignition loss	4.68
Insoluble	0.88
	95.30

This analysis refers to the nonmetallic portion. The oxide as a whole contained 20.10% of metallic particles. The remaining 4.70% in the reported analysis is presumably undetermined minor constituents. There is one other analysis of this oxide by Pugh,[4] but all the iron is reported as

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[1] *Popular Astronomy*, **47**, 93–97 (1939).

[2] *Pogg. Ann.*, **101**, 152–153 (1857).

[3] *Ann. chim Phys.*, 4th ser. **17**, 49–51 (1869). Incidentally, I have seen an analysis of terrestrial, nickeliferous magnetite with an almost identical composition.

[4] *Ann. d. Chem. u. Pharm.*, **98**, 385–386 (1856); Abstract in *Am. Jour. Sci.*, **24**, 295 (1857).

Fe_2O_3 and NiO is not reported at all. The agreement of the above with Pugh's analysis is not very close. Pugh found 25.04% of metal which was very rich in nickel (Fe:Ni = 4.97), as compared with his analysis of the metallic core of the piece from which he obtained the rust (Fe:Ni = 11.8). This is probably due to an enrichment in taenite as this is more resistant to oxidation than kamacite. The 20.10% of metallic particles reported by Van Arsdale contained a little oxide and was probably mostly metal as it appeared to be malleable instead of brittle as schreibersite would be. Pugh reported only 0.66% of this mineral, although it has been repeatedly reported in this as well as many other oxides. It has also been observed by the writer.

I have already reported on the frequent occurrence of zaratite as a green stain on meteorite rusts. In every case that I have examined, this stain has had the properties of zaratite, rather than nickel oxide or hydroxide as it is sometimes called. It would be natural to assume that it is derived from the metallic nickel in the meteorite. Some may have this origin, but while examining flakes of oxide from Xiquipilco I found evidence that it may possibly be derived from the $NiCl_2$ component of lawrencite. I observed globules like those formed by the exudation of lawrencite but instead of being brown or greenish, they were bright emerald green. Under the microscope they were isotropic like zaratite, but contained minute anisotropic specks. These could be unaltered lawrencite as $NiCl_2 \cdot 6H_2O$ is monoclinic. Microchemical tests showed the presence of chlorine and nickel, and acids produced an effervescence suggesting a carbonate. The action of moisture and carbon dioxide from the air on $NiCl_2$ might produce zaratite as follows:

$$3NiCl_2 + 9\,H_2O + CO_2 \rightleftarrows NiCO_3 \cdot 2Ni(OH)_2 \cdot 4H_2O + 6HCl.$$

Even if the equilibrium in a closed system should strongly favor the left side of the equation, the reaction could go to completion under natural conditions due to the volatility of the HCl.

It is certain that nickel is lost from the oxide in some form.[1] Whether or not this has any relation to the formation of zaratite is uncertain. The Toluca oxide, like most others, has lost some nickel. The NiO in Van Arsdale's analysis is equivalent to 4.04% metallic nickel. Most of the oxide used for this analysis was derived from the mass of uncertain origin already mentioned. This mass contained 7.29% Ni, which is typical of Xiquipilco.[5] Therefore, this oxide has lost about 3.25% Ni. The specific gravity of a large solid piece of this rust was 3.81.

A third constituent of meteorite rust is vivianite. I have never observed this myself, but it has been reported in the oxides of Santa Catharina, Brazil[6], and Magura (Arva), Hungary.[7] As this mineral occurs naturally with such iron oxides as bog ore, where it is probably derived from phosphates in the soil, it is not clear whether its occurrence with meteorite oxides is another instance of this kind, or whether it is derived from the oxidation of schreibersite. Since schreibersite is very resistant and is found unaltered in the oxides of both Santa Catharina and Magura, I am inclined to doubt that it is an oxidation product. If it were, it should be more common as schreibersite is abundant in some oxides but as far as I can determine, vivianite has been reported only twice.

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[5] *Popular Astronomy*, **45**, 103–106 (1937).

Since the oxidation of troilite forms sulphuric acid and iron oxide, it seems odd that no iron or nickel sulphates have been definitely reported. Since Lawrencite is retained in meteorites, soluble sulphates should be retained also. Nininger, digested one of his meteorodes[8] with tap water and the extract was found to contain the sulphate radical,[9] but unfortunately this radical might also have been present in the tap water. The only other possible sulphate containing mineral to be reported, so far as I am aware, is a basic nickel sulphate supposed to be analogous to copiapite. This was reported by Meunier in the oxide of Mezquital, Durango, Mexico.[10]

Since analyses of meteorite rusts almost always show more Fe_2O_3 than would be needed to form magnetite and trevorite from the FeO and NiO, and as the ignition loss must be mostly combined water, it seems inescapable that one of the hydrated oxides such as FeO(OH), is present. Hematite is also a possibility. Calcium carbonate has been reported but is undoubtedly derived from the soil.

[6] Daubrée, *Compt. rend.*, **85**, 1620 (1877).

[7] Clark, *Am. Jour. Sci.*, **15**, 16 (1853).

[8] *Trans. Kansas Acad. Sci.*, **32**, 63–67 (1929).

[9] *Am. Mineral.*, **23**, 536–537 (1938).

[10] *Compt. rend.*, **108**, 1028–1029 (1889).

A circular letter from the Director of the Geological Survey of Finland has been sent to numerous geologists in other countries. In the letter the Director calls attention to the destruction of property, including damage to the structure housing the headquarters of the Survey, as a result of the recent Russian-Finnish war. An appeal is made to friends of the Survey for assistance, particularly for publications for the library. The letter concludes with the following paragraph:

"Now that the Geological Survey of Finland has lost its headquarters, we venture to appeal to all geologists living in happier circumstances than ours, in the hope that they would organise in their respective countries a collection of means that would enable us to resume as soon as possible our participation in the geological study of our globe. We are confident that you will not, knowing that we have conscientiously carried out our own share of the world's geological work, refuse to give us all the aid in your power. Many small contributions can together denote an appreciable measure of help. The Geological Survey will commemorate in lasting form and honour those who helped it in its hour of need."

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB, INC.

The American Museum of Natural History, New York City, March 20, 1940

The meeting was called to order with 80 members and guests present. Mineral Day at the World's Fair, June 17, was announced and the members were urged to support it to make it as successful as possible. After the business meeting, the President introduced Mr. Thomas A. Wright, who spoke upon "The Spectrograph in Mineralogy." He showed slides illustrating modern instruments with their various advantages. A survey of the history of spectroscopy and spectrography was given and actual plates shown illustrating the practical applications of the technique. An interesting series showed many different tin minerals, while another drew comparisons between several of the micas. A number of calcite specimens from various localities showed some unexpected rare elements present. The talk was very interesting and well presented.

The American Museum of Natural History, New York City, April 17, 1940

The meeting was called to order with 62 members and guests present. The incumbent officers were reelected for another year. The speaker of the evening, Mr. John J. Shanks, of Waynesboro, Pa., spoke on the "Rocks and Minerals of South Mountain, Pa." The history of the geological work in this interesting region of pre-Cambrian rocks was first recounted, and then the interesting mineral deposits of the area described. A number of thin sections showing the intense alteration of the rocks and the growth of piedmontite were projected on the screen. At the close of the meeting the members had an opportunity to examine a large number of polished specimens of the altered rock and some of the minerals, such as copper, which are found in them.

F. H. Pough, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

The Academy of Natural Sciences of Philadelphia, Meetings of December 7, 1939, January 4, February 1, March 7 and April 4, 1940

Dr. W. Hershey Thomas presided on December 7, 1939 with 48 members and 30 visitors present. Dr. A. Williams Postel gave an illustrated talk on "The Granodiorites of the Philadelphia Area."

Dr. Thomas presided on January 4, 1940, with 37 members and 18 visitors in attendance. Dr. H. K. Alber addressed the society on "The Microchemical Analysis of Minerals," which was illustrated.

Dr. Thomas was in the chair on February 1, 1940, with 37 members and 17 visitors present. Dr. A. B. Cummins described "The Asbestos Minerals," emphasizing methods of mining and extraction in Canada. Mr. William Hunter reported on pitchblende from Avondale, Pa.

Dr. Thomas presided on March 7, 1940 with 39 members and 15 visitors present. Dr. Robert D. Butler spoke on "Mineral Collecting in Park County, Colorado," which was illustrated with maps.

Dr. Thomas presided at a meeting held on April 4, 1940, with 46 members and 29 visitors present. A minute expressing the regret of the Society on the death of Stephen Varni was read.

Mr. Ernest Weidhaas addressed the Society on "Freak Simulations in Minerals," illustrated by some of the extraordinary examples from his collection which includes famous specimens from the cabinets of George Frederick Kunz and John Calvert. Historical notes on such objects were given. Mr. Meier and Mr. Smith reported on natrolite, chabazite, and allanite from the Lenni quarry.

Mr. Samuel G. Gordon exhibited a model of a newly designed two-circle goniometer, constructed under his direction by Mr. Van Horn.

ALBERT JEHLE, JR., *Acting Secretary*

NEW MINERAL NAMES

Yamagutilite

KENJIRO KIMURA AND YOSIO HIRONAKA: Chemical investigations of Japanese minerals containing rarer elements. XXIII. On yamagutilite, a phosphorus-bearing variety of zircon, found at Yamaguti village, Nagano prefecture. *Jour. Chem. Soc. Japan*, **57**, 1195–1199 (1936). (In Japanese.) Abs. *Mineral. Abs.*, **7**, 263–264 (1939).

"Brown to dark-brown crystals with $p(111)$, $a(100)$, pp′ 56° 52′, D_4^{25} 3.971, gave SiO_2 21.35, P_2O_5 4.23, $(Zr,Hf)O_2$ 43.57, UO_2 2.08, ThO_2 3.52, rare earths 15.89, TiO_2 nil, $(Nb,Ta)_2O_5+SnO_2$ 0.54, Al_2O_3 0.48, Fe_2O_3 0.59, MnO 0.50, MgO 0.03, CaO 1.23, H_2O+ 6.08, CO_2 0.61; sum 100.70. X-ray powder photographs show that the high content of P_2O_5 is not due to intermixture with xenotime."

W. F. FOSHAG

New Zirconium Silicate

from the Lovozero Tundra

V. I. Gerasimovski: (Lomonosow Institute, Academy of Sciences, U.S.S.R.) "*Redkie Metalli*" (Rare Metals), **6**, No. 4, 42–43 (July–August, 1937).

Grains about 1.5 cm. in size. Color usually dark brown, rarely black. Streak dark brown. Fracture irregular. Lustre resinous. Cleavage absent. Hardness about 5. Analysis (by T. A. Burovoi) indicates ZrO_2 and $Nb_2O_5+Ta_2O_5$. Occurs with zircon, catapleite, lovenite and eudyialite in pegmatites on Muruar River and elsewhere in the Lovozero Tundra, Kola Peninsula, U.S.S.R.

W. F. F.

Ruthenosmiridium

Aoyama Shin'ichi: A new mineral "ruthenosmiridium." *Sci. Repts. Tohoku Imp. Univ., 1st Ser., Honda Anniv., vol.* (Oct. 1936) 527–546, 9 figures, 1 plate.

Name: From its relation to osmiridium, a *ruthenium osmiridium.*

Chemical Properties: An alloy of ruthenium, osmium and iridium, RuOsIr. Analysis: Ir 39.018, Os 38.885, Ru 21.080, Rh 0.986. Details of analysis given.

Crystallographical Properties: Hexagonal.

Physical Properties: Color tin white. Luster bright. Cleavage basal, perfect. G. = 18.97.

Occurrence: Found with steel gray and chalcopyrite-colored grains in the iridosmine, associated with gold in the gravels of the Uryu River, near Horokanai, Hokkaido, Japan.

W. F. F.

Djalmaite

Caio Pandiá Guimarães: Djalmaita, um novo mineral radioativo. *Ann. Acad. Brasil. Sci.*, **9**, 347–350 (1939) 3 figures.

Name: In honor of Djalma Guimarães, Brazilian petrologist and mineralogist.

Chemical Properties: Essentially a tantalate of uranium. Analysis: Ta_2O_5 72.27, Nb_2O_5 1.41, TiO_2 2.54, SnO_2 trace, ZrO_2 0.80, UO_2 2.17, UO_3 9.38 WO_3 0.18, Bi_2O_3 0.98, PbO 1.10, FeO 0.56, CaO 3.40, MgO 0.24, H_2O 4.62; sum 99.66.

Crystallographical Properties: Isometric. Habit octahedral. Forms, *o*(111), *i*(311)

Physical and Optical Properties: Color yellowish brown, greenish brown or brownish black. Streak yellow. G. = 5.75–5.88. H = 5.5. Fracture irregular, cleavage none.

Isotropic, $n = 1.97$.

Occurrence: Found in weathered pegmatite, with beryl (aquamarine), tourmaline, monazite, samarskite, columbite, etc., in the district of Brejaũba, Minas Geraes, Brazil.

W. F. F.

Lazard Cahn, widely known mineralogist and Fellow of the Society, died at Colorado Springs, Colorado, May 22, 1940. In 1928 Mr. Cahn served as Vice-President of the Society and in April 1927 a new boro-arsenate of calcium (cahnite) was named in his honor.